Mekelle University

College of Social Sciences and Languages
Department of Geography and Environmental Studies
Post Graduate Study Program

Assessment of spatio-temporal changes of wetlands using GIS and RS techniques in Dawa Chefa Area in the Northern Central Ethiopian Highlands

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Declaration

This is to certify that this thesis entitled "**Assessment of spatio-temporal change of wetlands and its socio-economic effect using GIS and remote sensing techniques in the Northern Central Ethiopian Highlands: A Case of Dawa Chefa Area**", submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Geography and Environmental Studies with specialization in GIS and RS at Mekelle University, department of Geography and Environ-mental Studies done by Kassaye Hussien Aragaw CSSL/PS066/04 is an authentic work carried out by him under our guidance. The matter embodied in this project work has not been submitted earlier for an award of any degree or diploma to the best of our knowledge and belief.

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Lists of Acronyms and Abbreviations

AOI: Area of Interest

ASTER: Advanced Space-Borne Thermal Emission and Reflection Radiometer

AVHRR: Advanced Very High Resolution Radiometer

CSA: Central Statics Agency

DEM: Digital Elevation Model

EMA: Ethiopian Mapping Agency

ERDAS: Earth Resource Data Analysis System

ETM: Enhanced Thematic Mapped

FCC: False color composite

GCP's: Ground Control Points

GIS: Geographic Information System

GPS: Global Positioning System

Ha: Hectare

LULCC: Land use Land Cover Change

LULC: Land-use and Land-cover

MLC: Maximum Likelihood Classifier

MT: Multi Temporal

NMA: National Metrological Agency

RGB: Red Green Blue

RS: Remote Sensing

SPOT: Satellite Pour l'Observation de la Terre

TIN: Triangulated Irregular Network

TM: Thematic Mapper

USGS: United States Geological Survey

UTM: Universal Transvers Mercator

USACE: United State Army Corps of Engineers

A.M.S.L Above mean sea level

Abstract

Wetland resources play an important role in sustaining human, plant and animal life. They balance climatic and hydrology cycle to our environment. However, wetlands have been decreased both in time and space. This in turn narrowed the opportunities of wetland services. Thus, the study focused on assessment of the spatio-temporal change of wetlands and its socio-economic effect in Northern Central Ethiopian highlands. Four sets of Landsat satellite imageries for the years of 1984, 1993, 2000 and 2013 were used to produce land cover maps and quantify the land use and land cover dynamics. Moreover; practical observation, structured questionnaire and focus group discussions were used to supplement remotely sensed satellite data. The qualitative data were then narrated. Unlike built up area expansion, grassland and farmland, the land use and land cover analysis showed that wetlands are reduced from the year 1984 to 2013. Overgrazing, water diversion for irrigated farm, waste dumping, and rapid population growth are the key driving forces of wetlands changes. Moreover, the study shows that wetland change brought social effect in the study area. In this regard, the shrinkage of the wetlands caused prevailing conflict between nomads and local farmers as both of them need wetland for different purposes. As they are more dependent on the wetland resources, the nomads were more resistant to the strategies of the government. The study also showed that wetland loss has controversial effects. In this respect when wetland loss increases swampy plants and animals also decreased and even later disappeared. Economically very important mangrove species started declining which directly affected the lives of nomads. Conversely, when wetland decreases, farmers encroach the wetlands for agricultural and grazing land due to the fact that it is very fertile and suitable for the application of modern irrigation. This is, however, at the expense of wetland loss. In conclusion, the study highlights that the wetland size has been decreased and brought ecological and socio-economic effect in the study area. Therefore, the government and other stakeholders should intervene by providing appropriate water management practices, awareness creation and family planning education to enhance sustainable land management and to meet the national and international interest linked to the Millennium Development Goals.

Key words: Wetland resources, wetland change, land use, land cover, GIS, RS, Dawa Chefa

Chapter 1: Introduction

1.1 Background of the study

Wetlands act as the biological "kidneys" of the landscape by filtering out any water that would otherwise directly run into a water system (Steve *et al.*, 1993). In addition, they have a paramount significance in balancing hydrologic cycle and providing important ecosystem services such as erosion control, food chain support, boosting agricultural production, fisheries, flood storage, water quality enhancement and carbon storage, wildlife habitat, and buffers during periods of high water (Johnson *et al*., 2003).

However, for a long time, a wetland was considered as a land area surrounded by water with little economic importance. People thought it was only habitat for hydrophytes and insects by neglecting the importance of wetlands in the whole ecosystem (Shi *et al*., 2013). Due to this misconception, studies conducted by different scholars have witnessed that there remains only few landscapes on the Earth that are still in their natural state (Zubair**,** 2006). Wetlands are among one of land uses on which tremendous change takes place. The quality and size of wetlands of the world have been changing overtime following the outcome of agro-pastoral activities such as farming, cattle rearing, urban use, and affected by natural factors like drought (Ndzeidze *et al*., 2008).

Wetland areas are decreasing during the past 50 years due to different agents related to wetland reclamation, population pressure, desertification, climate change, and misguiding policies (Augustine and Warrender *et al*., 1998). Furthermore, the wetland of developing countries particularly in sub-Saharan Africa countries nowadays are underwent a fast habitat degradation and loss (Ndzeidze *et al*., 2008). As a result the ecological, socioeconomic and environmental advantage of wetland has decreased.

If wetlands are given due attention and are properly managed, they can play a significant socio economic and ecological role in sustaining human, plant and animal life (Ramsar Convention, 2006). Investigating spatio-temporal wetland change on the other hand is essential due to the reason that most of wetlands are now under bad condition due to lack of effective land management, urban expansion, poverty and lack of awareness (Rao, 2009). Hence, analysis to monitor and change detection of wetland nowadays is possible using Geographic information systems (GIS) and remote sensing (RS) data which are ascertained as the most appropriate tools.

This research used GIS and RS techniques to analyze the spatio-temporal changes in wetlands in the North Central highlands of Ethiopia in the case of Dawa Chefa area.

1.2 Statement of the problem

Wetlands are increasingly at risk from human alteration of the landscape (Vance *et al*., 2009). Activities within and surrounding the catchment lead to degradation by changing wetland hydrologic function, increasing nutrient and sediment loads, and providing a conduit for the spread of invasive and exotic species. Moreover, Ghobadi and Pradhan (2012) stated that loss of wetland results in the loss of surface water quality, destruction of wild life habitat, loss of biodiversity, flooding, erosion and environmental degradation.

Wetlands have been witnessed remarkable change in the past periods. This has, therefore, resulted in the effects on the existing biodiversity. Particularly, in areas where the human dwellers are around the wetlands, there is massive loss of wetland (Vance *et al*., 2009).This is because of the reason that people exploited the wetlands ecosystem exhaustively. In line with this idea, most of the people in Dawa Chefa are both agrarian and pastoralist community that highly depends on unmanaged farm and grazing land. For instance, during dry season the nomads graze their herds around the wetland.

However, there is no systematic study that highlights the trend and magnitude of the wetlands and their effect on the local people in Dawa Chefa wetland. Such fragmented knowledge about the condition of wetlands gives little attention to be taken by the government. This indicates that decision makers do not have correct information to develop directives and strategies for natural resource management and monitoring environmental changes in the wetlands. Therefore; this study was conducted to evaluate and map the status of the wetland changes of the study area using GIS and RS techniques between the years 1984 and 2013 so as to forward and encourage development interventions. Thus, the research will be important to decision makers in terms of developing strategies for natural resource management and monitoring environmental changes in the study area and areas that have similar geographic setting.

1.3 Objectives

1.3.1 General objectives

The general objective of the research is to analyze the spatio-temporal changes of wetlands in Dawa Chefa area using GIS and RS techniques for the past 30 years.

1.3.2 Specific objectives

1) Analyze the spatio-temporal wetlands changes between1984-2013.
2) Identify the responsible factors for wetland changes of Dawa Chefa area.
3) Identify the socio-economic effects of wetland change in Dawa Chefa area.
4) Suggest possible recommendations for proper wetlands use management.

1.4 Research questions

On the basis of the research objectives the following questions need to be answered in this Particular study:

1. Is there spatio-temporal LULC dynamics of the study area for the last three decades?
2. Were there changes in the wetlands in the study area for the last 30 years?
3. What were the major factors behind wetland change in Dawa Chefa area?
4. What is the rate of wetland change?
5. What are the socio-economic effects of wetland change in Dawa Chefa area?

1.5 Significance of the study

Wetlands loss has direct impact on the loss of biodiversity, loss of surface water quality, loss of ground water table, intense flood, loss of wild life habitat and environmental degradation. Thus, this study provides information to conserve and protect wetlands in order to maintain natural balance in the study area. The study could also provide relevant information to contribute in the environmental management plans and improves wetland change planning issues in the study area. Lastly, it provides the latest information about causes and consequences of wetland change for environmentalists, regional planners, and decision makers to come up with sustainable environmental development and protection. It will also be important means of information for other researchers for further research undertakings.

1.6 Delimitation of the study

Geographically, the scope of this study was limited to analyze the spatio-temporal wetland change in Dawa Chefa area for the last 30 years (from 1984 to 2013). Satellite image data limited to four selected years Landsat image of the wetland area (from 1984 up to 2013) which were used to detect the change in the study area. Socio-economically, the study was limited to analyze trend of irrigation, farmland expansion, urbanization, villagization and changes of kind and importance of wetlands ‘vegetation (especially *Filla*) and other mangroves for the local community following changes in wetlands.

1.7. Limitations of the study

Although the researcher tried his best to meet the pre-stated research objectives and attempted to answer the predefined research questions by mapping the spatio temporal wetlands in Dawa Chefa area, there are sort of limitations faced in the course of conducting the research. Time, lack of high resolution images, finance and limited network connection to down load images were the major limitations.

1.8 Organization of the thesis

This research was organized into five chapters. The first part contains the background, objectives, research questions, significance, delimitation, limitation and organization of the thesis. The second chapter is devoted to review of related works to share the methodology and scientific evidences from related studies. The third chapter deals with the description of the study area using various elements relevant to this particular research. It also presented the methods employed including data types and sources, software and instruments utilized to conduct the research. The fourth chapter deals with the results and discussion parts of the thesis. The last chapter presents the conclusion and recommendations of the study.

Chapter 2: Literature Review

2.1 Land use and land cover dynamics

Every parcel of land on the Earth's surface is unique in the cover it possesses and on the way it is used. Land use and land cover is distinct yet closely linked characteristics of the Earth's surface. Land cover is defined as is "the observed biophysical cover on the earth's surface (FAO, 2000).Land use is "the arrangements, activities and inputs that people under-take on a certain land cover type". Land use differs from land cover because of the intentional role of people to adapt the natural land cover to their benefit (FAO, 2000).The land use entails both the manner in which the biophysical attributes of the land are manipulated, and the intent underlying that manipulation, namely, the purpose for which the land is used (Abiy *et al*., 2010). Thus, land use often influences land cover (Lemlem *et al*., 2007). Land cover can be directly observed on aerial photographs and satellite imageries (Girmay *et al*., 2003). Changes in the nature of land use activities often results in land cover changes, which are categorized into two types: modification and conversion. Modification is a change of condition within a cover type in which significant change in land cover can occur within these patterns of land cover change. Conversion is a change from one cover type to another (Meyer, 1994).

2.2. Wetlands

Wetlands are the lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water (Charles *et al*., 1979). The United State Army Corps of Engineers (USACE *et al*., 1987) defined wetlands as "Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions". Wetlands are areas where a water table is at, near, or just above the surface and where soils are water saturated for a sufficient length of time such that excess water and resulting low soil oxygen levels are principal determinants of vegetation and soil development. Wetlands have a relative abundance of obligate hydrophytes in the vegetation community and soils featuring "hydric" characteristics (Banner and Mackenzie *et al*., 2000). Moreover, based on Ramsar Convention wetland area are composed of the wide variety of habitats such as marshes lands, peat ponds, floodplain, rivers and lakes and coastal areas such as salt marshes, mangroves, and sea grass beds but also coral reefs and others marine areas no deeper than six meters at low tide, as well as human made wetlands such as waste water treatment reservoir (Malik *et al*., 2011).

Wetlands generally include swamps, marshes, bogs, and similar areas (Frazier et al, 1996). It is also believed that there are two general types of wetlands on earth. The first one is freshwater wetlands (95%) and the second one is marine or estuarine (saltwater) wetlands (5%).In turn, the former one has been divided in to three dominant categories are forested wetlands, emergent wetlands and shrub wetlands (Shi *et al*.,2013).

Wetlands are lands where water collects on the land surface long enough to promote soil development and support the types of plant and animal communities adapted to saturated conditions. Wetlands are small or large, expansive areas of the landscape where the water table is at or near the surface or where the land is covered by shallow water for much of the growing season. Wetlands are discrete entities and lie between unsaturated terrestrial upland and aquatic deep water in the landscape mosaic (Ontario Ministry of Natural Resources, *1997*).

Wetland of the study area grouped under the freshwater- wetland which includes swamps, marshes and bogs which are covered with mangroves, large sized grasses (in the locality they are called *Kietema* and *Filla*), small sized grasses and other water hydrophytes plants.

2.2.1 Functions of wetland

Wetlands are one of the world's most important environmental assets, containing a disproportionately high number of plant and animal species compared to other areas of the world. Throughout history they have been integral to human survival and development. Wetlands play a critical nature balancing role in the ecosystem in different ways (Osmond and Line *et al*., 1995).

2.2.1.1 Hydrologic flux and storage

Wetlands store precipitation and surface water and then slowly release the water into associated surface water resources, ground water, and the atmosphere (Davis *et al.*, 1994). Wetland types differ in this capacity based on a number of physical and biological characteristics, including: landscape position, soil saturation, the fiber content/degree of decomposition of the organic soils, vegetation density and type of vegetation. Values of wetlands as a result of the functions of hydrologic flux and storage include: water balance, ground water recharge, climate control, oxidation-reduction, water quality, water supply, flood control, erosion control, wildlife support, recreation, culture, and commercial benefits (the National Wetlands Working Group, 1987).

2.2.1.2. Biogeochemical cycling and storage

Wetlands play a greater role to be a sink for (or transform) nutrients, organic compounds, metals, and components of organic matter. They also act as filters of sediments and organic matter, and a permanent sink for these substances if the compounds become buried in the substrate or are released into the atmosphere. Wetland processes play a role in the global cycles of carbon, nitrogen, and sulfur by transforming them and releasing them into the atmosphere (Osmond,Line *et al*., 2012).

2.2.1.3. Biological productivity

Wetlands are among the most productive ecosystems in the world. Immense varieties of species of microbes, plants, insects, amphibians, reptiles, birds, fish, and other wildlife depend in some way on wetlands. Wetlands with seasonal hydrologic pulsing are the most productive. Wetland plants play an integral role in the ecology of the watershed. They provide breeding and nursery sites, resting areas for migratory species, and refuge from predators (Osmond *et al*., 2012). A wetland with more vegetation intercepts more runoff and be more capable of reducing runoff velocity and removing pollutants from the water than a wetland with less vegetation (Osmond *et al*., 2012). Wetland plants also reduce erosion as their roots hold the stream bank, shoreline, or coastline. Generally, values associated with biological productivity of wetlands include: water quality, flood control, erosion control, community structure and wildlife support, recreation, aesthetics, and commercial benefits.

2.2.1.4. Decomposition

Wetland creates suitable condition for the decomposition of organic matters. The nutrients and compounds released from decomposing organic matter may be exported from the wetland in soluble or particulate form, incorporated into the soil, or eventually transformed and released to the atmosphere. Decomposed matter (detritus) forms the base of the aquatic and terrestrial food web (Osmond *et al*., 2012).

2.2.2. Wetland change

Wetlands are progressively degrading due to land use changes in many countries with the expansion of agriculture and the development of water resource infrastructure being amongst the major drivers of adverse change globally (Ndzeidze *et al*., 2008). Though actual extent of wetland loss globally is not well known, in some areas more than 50% and sometimes more than

85% of specific wetland types have been lost. But it has not been possible to yet ascertain with any certainty the extent of wetland loss globally (Nagabhatla and Finlayson *et al.,* 2002). Furthermore, with the increasing influence in climate change and human activity or population pressure, wetland reclamation, water diversion, dam construction, pollution, biological incursion, desertification, and misguiding policies more and more wetlands of our plant are under shrinking from time to time (Augustine and Warrender *et al*., 1998). Specially, during the past 50 years. (Ghobadi and Pradhan *et al*., 2012).

2.2.3. Causes of wetlands change

Physical and human mad factors are being amongst the major drivers of adverse wetland change globally (Ramsar Convention, 2006). Above all, population pressure and its intervention to the environment is the responsible factor for imbalance of nature in general and wetland change in particular. Human activities that resulting in wetlands loss and degradation include: agriculture, commercial and residential development, road and other constructions, impoundment, resource extraction, industrial (sitting, processes, and waste), dredge disposal, silviculture, and mosquito control. Besides this, pollutants causing degradation are sediment, nutrients, pesticides, salinity, heavy metals, weeds, low dissolved oxygen, pH, and selenium (USEPA *et al*., 1994). In contrary to developed nations where construction is the major driving force factor for wetland change, in developing countries agricultural land expansion is the major driving force factor due to alarming rate of population pressure.

2.2.3.1 Agriculture

Historically, agriculture has been the major factor in freshwater and estuarine wetland loss and degradation. Not only agricultural land expansion but also any other agricultural activities such as harvesting food, fiber, or forest products; minor drainage; maintenance of drainage ditches; construction and maintenance of irrigation ditches; construction and maintenance of farm or forest roads; maintenance of dams, dikes, and levees; direct and aerial application of damaging pesticides (herbicides, fungicides, insecticides, fumigants); and ground water withdrawals performed in wetlands can degrade and alter a wetland's hydrology, water quality, and species composition. Furthermore, excessive amounts of fertilizers and animal waste reaching wetlands in runoff from agricultural operations, including confined animal facilities, can cause eutrophication (USEPA *et al*., 1994).

2.2.3.2. Grazing

Grazing livestock can degrade wetlands that they use as a food and water source. Urea and manure can result in high nutrient inputs. Cattle traffic may cause dens and tunnels to collapse the wetlands. As vegetation is reduced, stream banks can be destroyed by sloughing and erosion. Stream bank destabilization and erosion then cause downstream sedimentation (Ndzeidze *et al*., 2008).Sedimentation reduces stream and lake capacity, resulting in decreased water supply, irrigation water, flood control, hydropower production, water quality, and impairment of aquatic life and wetland habitat. The economic losses attributed to the reduced quality and quantity of water and habitat from overgrazing of riparian wetland vegetation is more than $200 million. The depletion of vegetation from riparian areas causes increased water temperatures and erosion and gully formation, prevents runoff filtration, and eliminates food and cover for fish and wildlife (USEPA *et al*., 1994). If stocking of livestock is well managed, grazing can coexist with wetlands, benefiting farmers and increasing habitat diversity.

2.2.3.3. Urbanization

Urbanization is a major cause of impairment of wetlands .Urbanization has resulted in direct loss of wetland acreage as well as degradation of wetlands. Degradation is due to changes in water quality, quantity, and flow rates; increases in pollutant inputs; and changes in species composition as a result of introduction of non-native species and disturbance. The major pollutants associated with urbanization are sediment, nutrients, oxygen-demanding substances, road salts, heavy metals, hydrocarbons, bacteria, and viruses. These pollutants may enter wetlands from point sources or from nonpoint sources. Construction activities are a major source of suspended sediments that enter wetlands through urban runoff (USEPA *et a*l., 1994).

As roads, buildings, and parking lots are constructed, the amount of impervious surface increases. Impervious surfaces prevent rainfall from percolating into the soil. Rainfall and snowmelt carry sediments; organic matter; pet wastes; pesticides and fertilizers from lawns, gardens, and golf courses; heavy metals; hydrocarbons; road salts; and debris into urban streams and wetlands . Increased salinity, turbidity, and toxicity; and decreased dissolved oxygen, all affect aquatic life and, therefore, the food web Excessive inputs of nutrients can lead to eutrophication or result in the release of pollutants from a wetland into adjacent water resources (USEPA *et al*., 1993).

2.2.3.4. Roads and bridges

Roads and bridges are frequently constructed across wetlands since wetlands have low land value. It is often considered to be more cost effective to build roads or bridges across wetlands than around them. Roads can impound a wetland, even if culverts are used. Such inadvertent impoundment and hydrologic alteration can change the functions of the wetland. Road and bridge construction activities can increase sediment loading to wetlands. Roads can also disrupt habitat continuity, driving out more sensitive, interior species, and providing habitat for hardier opportunistic edge and non-native species.

Roads can impede movement of certain species or result in increased mortality for animals crossing them. Borrow pits (used to provide fill for road construction) that are adjacent to wetlands can degrade water quality through sedimentation and increase turbidity in the wetland. In addition to this, the maintenance and use of roads contribute many chemicals into the surrounding wetlands. Rock salt used for deicing roads can damage or kill vegetation and aquatic life (Ndzeidze *et al*., 2008).

Herbicides, soil stabilizers, and dust palliatives used along roadways can damage wetland plants and the chemicals may concentrate in aquatic life or cause mortality. Runoff from bridges can increase loadings of hydrocarbons, heavy metals, toxic substances, and deicing chemicals directly into wetlands. Bridge maintenance may contribute lead, rust (iron), and the chemicals from paint, solvents, abrasives, and cleaners directly into wetlands below (USEPA, 1994).

2.2.4. Consequences of wetland loss

Losses of wetlands have numerous negative impacts in the ecosystem. Of these the major consequences of wetlands loss are unbalanced hydrological cycle, unbalanced food chain, loss of wild life habitat, loss of water retention, decrement of agricultural production and fisheries, absence of flood storage, absence of hydrologic flux and storage, loss of biogeochemical cycling and storage, disappearance of biological productivity and absence of decomposition of organic matter (Zubair, 2006).

2.3. Application of GIS and RS in wetland change detection

2.3.1. Application of RS in wetlands monitoring

Remote Sensing (RS**)** is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object. Following the footstep of 1980s, viewing the earth from space has become possible to gather information regarding human utilization of natural resource and understand the effect of human activities on natural resource using satellite imagery including wetland change studies. Major data sources for such analyses include Land sat, Satellite Probationer d'Observation de la Terre (SPOT), radar, and Advanced Very High Resolution Radiometer (AVHRR).

Land sat multispectral and temporal imagery is a particularly important source of data for observing changes in wetlands. This is because it provides continuous coverage since the 1970s and contains bands that are sensitive to changes in vegetation coverage and soil moisture. Hence, remote sensing provides a unique opportunity to characterize the spatio-temporal distribution of these changes and to collect important baseline wetland information that is too difficult to obtain using field-based methods. Early images paired with more recent images can be used to detect changes in the landscape over that period (Ndzeidze, 2008).

Remotely sensed images are being used to address critical wetland resource management problems, providing researchers with the ability to make rapid decisions about large spatial areas using recent data (Twumasi and Merem, 2006). Wetland dynamics operate at multiple spatial and temporal scales; require researchers to be able to make multi-scale observations using satellite images. Therefore, satellite images can easily detect and map both local and large area land use/land cover changes, and the impact they have on wetland processes (Ndzeidze. 2008).

Classifying wetlands is the basic step for wetlands inventory. After that, wetland changes can be detected from the classified images. At the global level, it provides readily understood terms, a framework for international legal instruments for wetland conservation, and assists in the dissemination of information (Scott & Jones, 1995). Recently, digital classification of wetland from satellite image data has been widely used because these methods are less time consuming and the source data provide high temporal resolution and high accuracy in georeferencing procedures (Jensen 1996, Coppin *et al*., 2004).

Many datasets have been successfully used in wetland classification, such as aerial photographs; Land sat data, and System Pour l'Observation de la Terre (SPOT) data. But Land sat-based classification is considered providing the greatest accuracies (Civco 1989, Hewitt 1990, Bolstad and Lillesand, 1992) because of the sensitivity of Land sat bands. The Land sat TM and ETM+ have similar 7 bands, while ETM+ band 6 has a higher resolution of 60 meters. The Land sat 7 satellite also has newly added panchromatic band 8 with resolution of 15 meters, TM band 1 can detect water for bathymetric (water depth) mapping along coastal areas and is useful for soil-vegetation differentiation and for distinguishing forest types.

TM band 2 can detect green reflectance from healthy vegetation, and band 3 is designed for detecting chlorophyll absorption in vegetation. TM band 4 is ideal for near-infrared reflectance peaks in healthy green vegetation and for detecting water-land interfaces. The two mid-infrared bands on TM are useful for vegetation and soil moisture studies, and discriminating between rock and mineral types. The thermal-infrared band on TM is designed to assist in thermal mapping, and for soil moisture and vegetation studies (Table1).Unsupervised and supervised classification techniques are most common approaches in wetlands analysis (Ozesmi & Bauer, 2002).

The main difference between supervised and unsupervised classification methods is that in supervised classification, the users need to create the training sites to identify the pixel that belongs to which class. Then the remaining patterns will be identified as the members of each predefined class during classification. But in unsupervised classification, the pattern is assigned to a hitherto unknown class. One limitation of supervised classification is the misclassification happened in creating training sites will affect the final classified results. For example, with supervised maximum likelihood classification method, Ndzeidze (2008) chose the Region of Interest tool (ROI) to create training sites of pixels. Every selected pixel, both within and outside the training sites, was evaluated and assigned to the class where it had the highest likelihood of being a member. In this research six major LULC classes (wetland, built up, bush land, forest, grass land and farmland) were used to detect wetland change.

2.3.2. Digital image processing of satellite images

Digital image processing refers to the processes of manipulating, managing and digital enhancement to facilitate better visual interpretation of digital images by a computer system. This is done to extract useful information from the image. Digital image processing is largely concerned with four basic operations: image restoration, image transformation, image enhancement, and image classification (Lillesand *et al*, 2000). Before the main data analysis and extraction of information, pre-processing or restoration and rectification was done to correct for sensor and platform-specific radiometric and geometric distortions of data (Lillesand, 2000). Resampling procedure was used to determine the digital values to place in the new pixel locations of the corrected output image. This is done in order to geometrically correct the original distorted image (Lu and Weng, 2007).

Table 1: Land sat TM Bands and wavelength range

Band	**Band Region**	**Wavelength**	**Specific Application**	**Resolution(m)**
1	Blue-green	0.45 - 52 µm	Soil and vegetation discrimination and Bathymetry and coastal mapping	30
2	Green	0.52 - 0.60 µm	Vegetation mapping and cultural/urban features mapping	30
3	Red	0.63 - 0.69 µm	Vegetated and non-vegetated mapping	30
4	Near IR	0.76 - 0.90 µm	Delineation of water body and Soil moisture discrimination	30
5	Mid IR	1.55 - 1.75 µm	Vegetation moisture discrimination and Soil moisture discrimination	30
6	Thermal IR	10.4 - 12.5 µm	Vegetation and soil moisture analysis andThermal mapping	120
7	Mid IR	2.08 - 2.35 µm	Discrimination of mineral and rocks and Vegetation moisture analysis	30

(Source:Lemlem Abraha)

2.3.3. Application of GIS in wetland change detection

GIS is a tool used for systematic spatial data collection and processing. It can be used to study the environment by observing and assessing the changes and forecasting the future based on the existing situation (Gezahegn, 2013). Modern GIS gives users the ability to conduct visual and quantitative analysis involving multiple kinds of digital spatial data, including remotely sensed imagery. In most studies, Land sat data after classification are combined with GIS data for future wetland analysis. Sader *et al*, (1995) used both supervised and unsupervised classification methods to map the Land sat data. Then, ancillary, topography, geology, hydrology and Geographic Information System (GIS) data sources are used to model forested wetland characteristics. With GIS, different component layers can be overlaid to investigate relationships between individual wetlands (Sader *et al*,. 1995).

Classified images can be combined with additional shape files, such as permanent water bodies, rivers, soils types and population changes (Mahmud et al., 2011). These data provide extra information to detect the changes of wetlands and potential causes of the changes. GIS can be used to perform area calculations on the classified images. The index, such as soil hydrologic group, land use/soil type combination, groundwater residence time, and location of septic system can be calculated by GIS to estimate the necessary data input (Poiani 1996).

Chapter 3: Methods and Materials

3.1 Description of the study area

3.1.1 Geographic location

The study area is located in Amhara national regional state, South Wollo Zone in the three Woredas of Oromia liyu Zone (Figure1). The three Woredas, in which the study area is found, are Dawachefa, Antsokia Gemza and Artuma Fursina (Figure1). Woreda is equivalent to a district and are managed by a local government in Ethiopia.

Astronomically, it lies between 10º, 20' 0"N and 10º, 55' 0"N latitude, and 39º, 40' 0"E and 40º, 10' 0"E longitude locations. The total area of the study area is about 250,175.25 hectare (ha). The wetland is surrounded by the Northern Shoa massifs in the West, the Wollo Massifs in the North and the Dawa Chefa hill ridges in the East. In addition to this natural land features, the wetland is encompassed by manmade features such as roads and towns (Figure1). Kemissie, Woledi, chereti, Chefa Robit towns and other compacted villages are settled along the main asphalte road which is from Addis Ababa to Dessie in the East of the wetland. Mekoy, Majetie and other small towns are settled along the gravel road in the West of the wetland. The wetland has elongated shape following Borkena River which drains from highlands of Wollo.Other major and minor rivers from Northern shoa high lands and the Eastern hill ridges of Dawa Chefa flow in to the wetland.

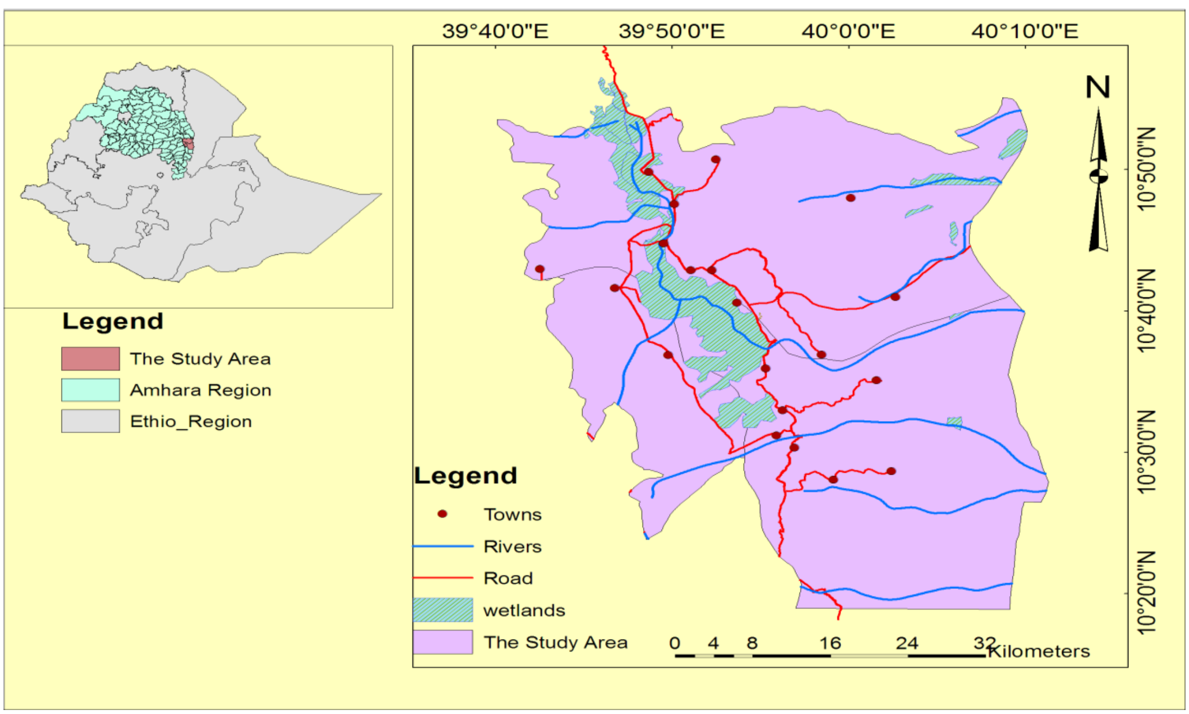

Figure 1.The location Map of the study Area

3.1.2 Climate

3.1.2.1 Rainfall

The rainfall data between 1963 and 2013 is shown in Figure 3 was based on data from Kombolcha meteorological station which is about 10 km north of the study area. Rainfall is unimodal with small monthly rainfall occurring from March to May, and October to November and the high rainfalls between Junes and September. The average annual rainfall of the area is 1557 mm. Three months (December, January and February) receive the least amount of rainfall. More than 76% of the total rainfall occurs between June and September (kiremt season), when cropping normally takes place. Twenty percent of the total amount of rainfall occurs in the months of April, May, October and November and less than 3% occurs in January, February, March and December. The highest and lowest rainfall occurred in the years 1999 & 1994 with annual rainfall of 1958.9 mm and 1316.0 mm, respectively (Figure2).

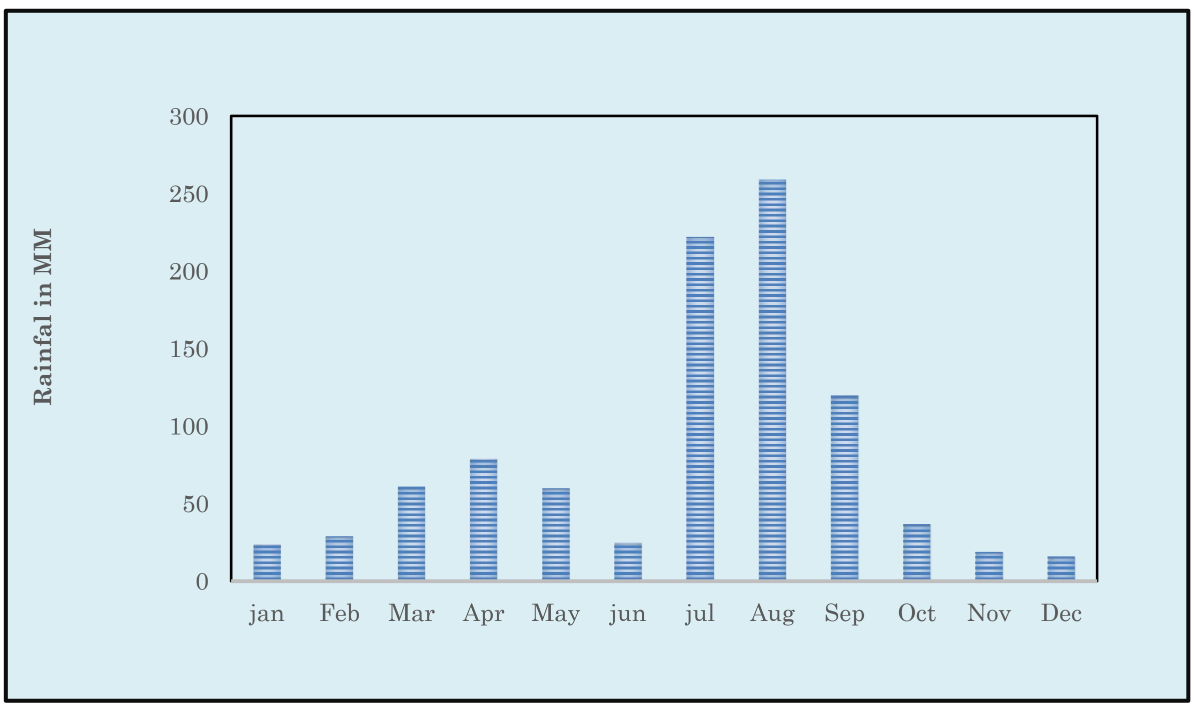

Figure 2.Mean annual Rainfall distribution of the study area

3.1.2.2 Temperature

Temperature variation spatially and seasonally depends on latitude, altitude, humidity and wind regime. In Ethiopia the mean maximum and minimum temperature vary significantly by season and area; the annual variation ranges from 2 to 6ºC (Sanchez, 1976). Comparison of temperature data within the time frame considered in this study, i.e. between 2004 and 2013, shows that the average minimum and maximum annual temperatures to be 24.5^{0}C (in 2011) and 19.7ºC (in 2005), respectively. The highest mean monthly temperature was recorded for the months of April (24.5ºC), May (25.2ºc), June (26ºc) and July (24.1ºc).Whereas, the lowest mean monthly temperature was recorded in the months of November (20ºc), December (19.3ºc) and January (20.2ºc) (Figure3)

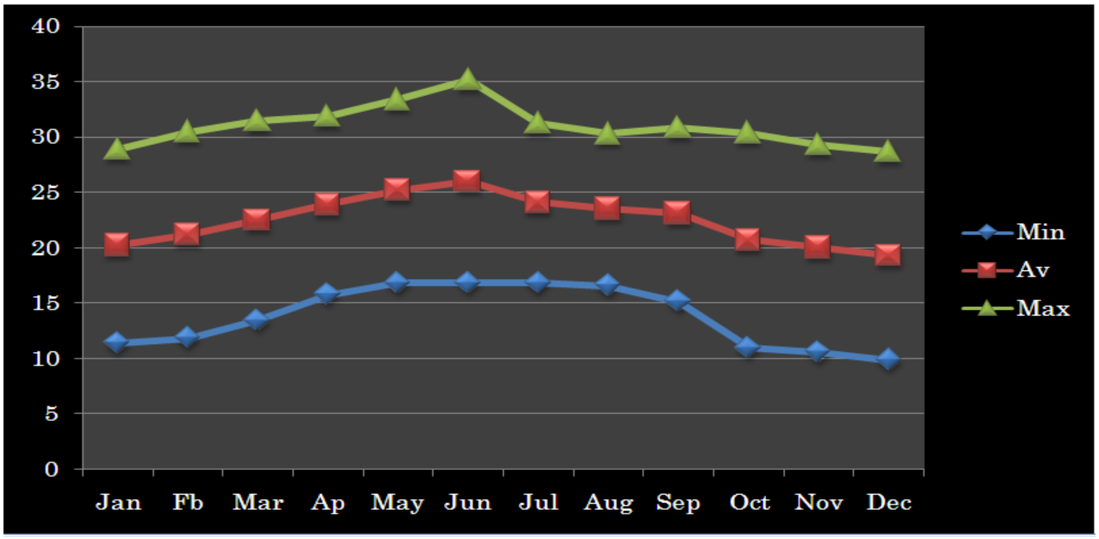

Figure 3. Mean annual temperature of the study area (from the year 2004 to 2013)

3.1.3. Physiographical setting of the study area

Topographic nature of the study area is consists of various types of land forms (Figure 4). Valleys, mountain ridges (in the Western part of the study area), plateaus, extensive plain areas (the major part of the wetland area), hills (in the Eastern part of the study area), dissected valleys (in the Western part) are the major element of landforms of the study area. The elevation variation ranges from 900 m to 3500 m (a.m.s.l). The highest elevation is found to the West of the study area which is part of the Northern Shoa mountain ridge in the central or Shoan plateau. This mountain belt is an extension of the western escarpment of the great East African Rift Valley system (Abiy, 2010). The Northern Shoa mountain ridge is the major headwater of the study area. The major physiographic elements of the study area were analyzed below using ArcGIS10.

3.1.3.1Topography and Drainage

The study area is surrounded by South Wollo massifs in the North, the North Shoan massifs in the West and hill ridges of Dawa Chefa Woreda in the East. The North Shoan mountain belt is an extension of the western escarpment of the great East African Rift Valley system. So, the study area is the most Western part of the Great East African Rift Valley system (Figure4). The North Shaon Mountains are important water source like a tower that supports the life of thousands of people living in the adjacent lowland areas. Due to this the area has a centripetal drainage pattern which discharges from the surrounding highlands to the center of the lowland area which is the area at which most part of the wetland is found.

Borkena River from South Wollo massifs, small and large rivers such as Dargie, Sala and Gudaber from North Shoa mountain ridges and Workie and Dolu Rivers from Dawa Chefa mountain ridges are the main water source of the wetland. Of all these major and minor rivers of the watershed, Borkena, Dollu, Workie and Dargie are perennial rivers and others are intermittent rivers. Almost all of the rivers cross one or more towns along their way. Due to this the rivers carry solid and liquid waste material from the town that they cross to the wetlands (Figure1).

Based on the local topographic characteristic (the difference between highest and lowest elevation) of the study area, the major landform elements were mapped using SRTM 30m DEM. The major land form components of the study area include plateau, valley, and some undulating hills and mountains with maximum elevation of 3188 meters above sea level (Figure4).In general, the study area is the most Western part of the Great East African rift valley with dissected, rugged mountains and spurs in West, undulated plain land and hills and escarpments in the center and low land areas in the East (Figure4).

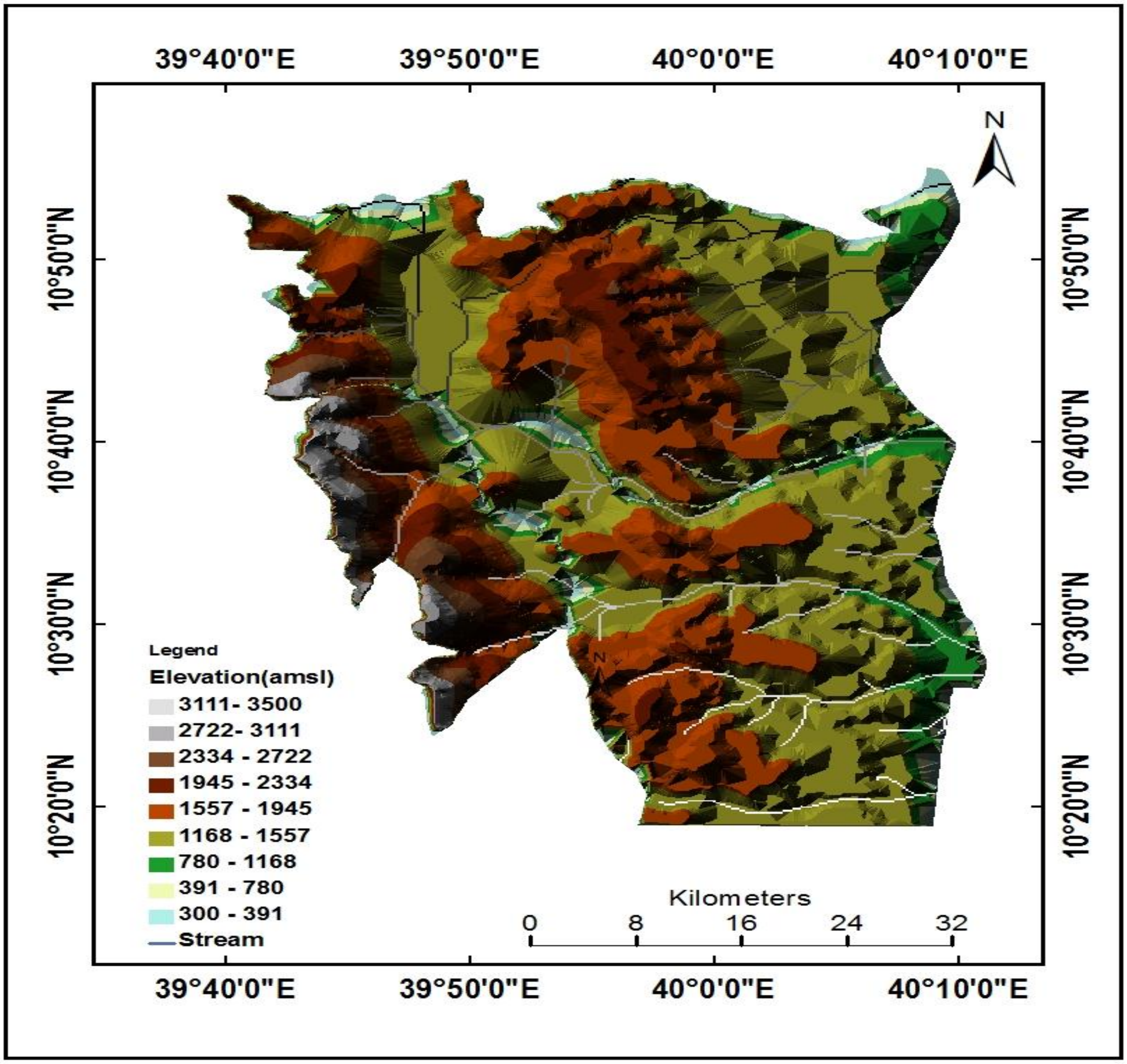

Figure 4. Elevation and drainage map of the study area

3.1.3.2 Soil classification

The soil for the study area includes predominantly Chromic Cambisols, Eutric Cambisols and Chromic vertisols where the Chromic Cambisols dominates the eastern part of the study area and the Chromic vertisols occupies the southern, south western and north western area of the study area. Besides majority of the central part of the study area is dominated by Eutric regosols.

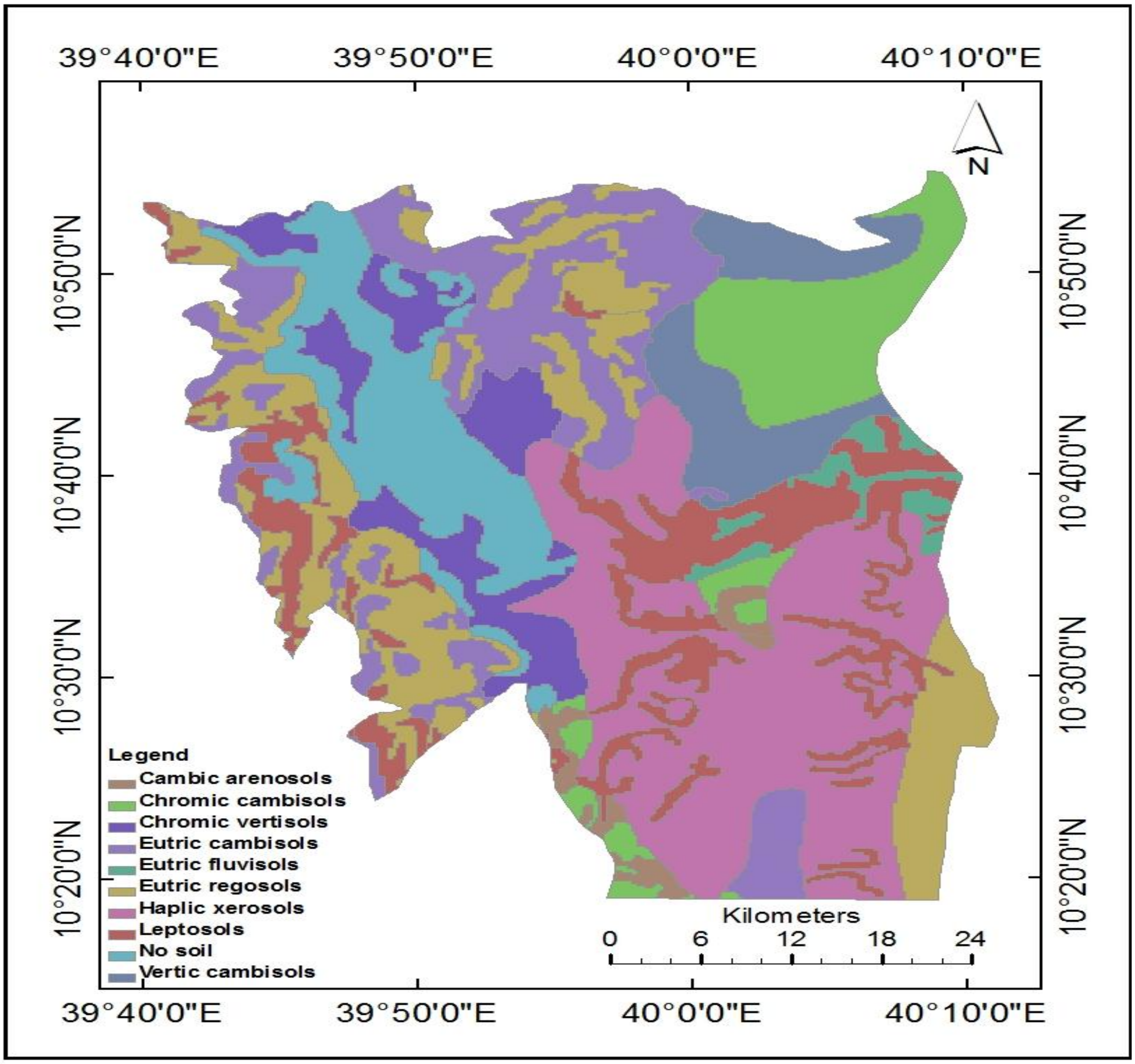

Figure 5. Soil Classification map of the study area (Source Ministry of water, 2013)

3.1.3.3 Aspect

Aspect is compass direction that a topographic slope faces, usually measured in degrees from north. Aspect maps are often color-coded to show the eight major compass directions, or any of 360 degrees. Aspect identifies the steepest down slope direction from each cell to its neighbors (Figure6).

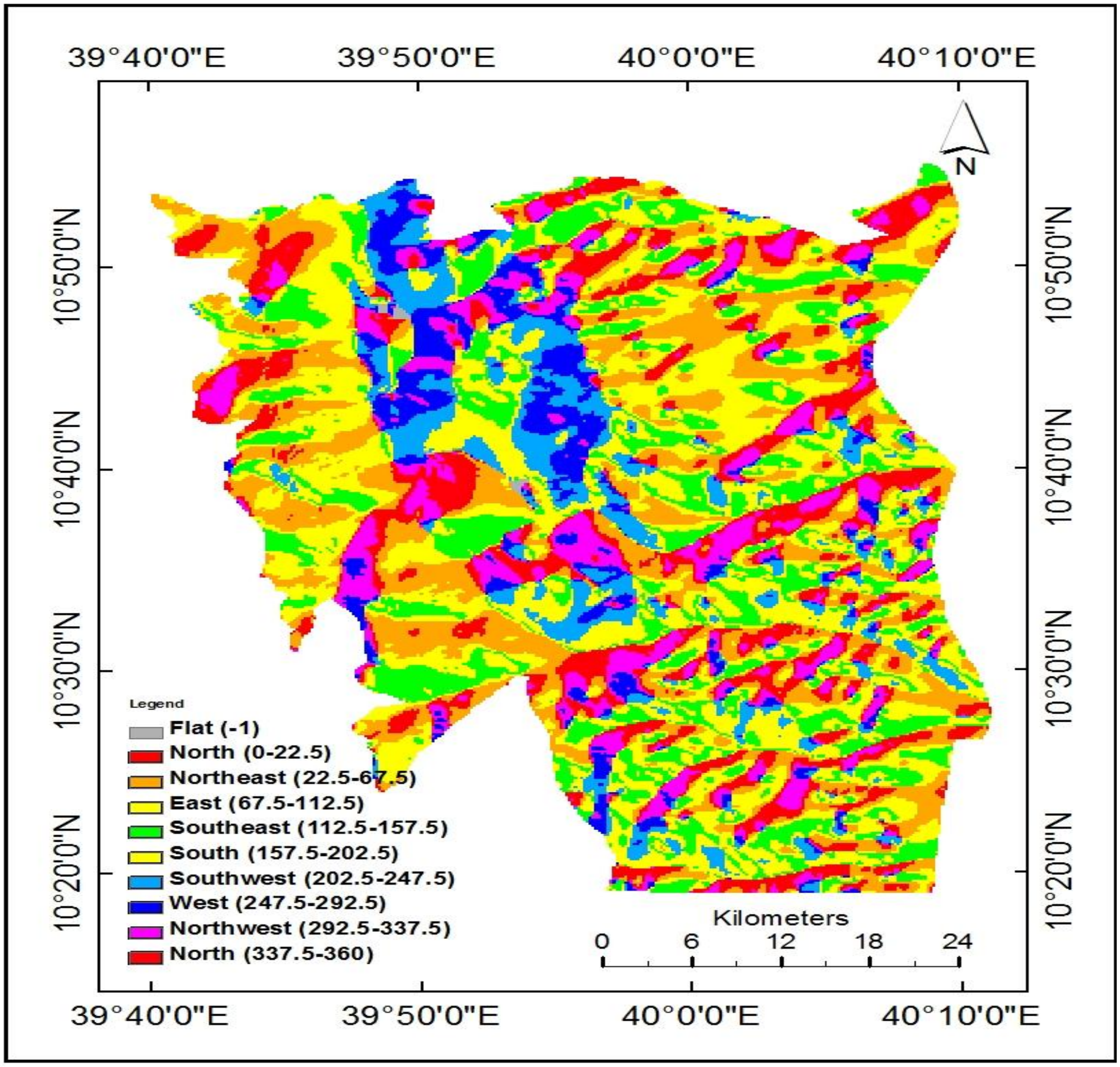

Figure 6. Aspect map of the study area (Source, Aster Global DEM Website)

3.1.4 Population

The study area has a total population of 180114 based on the 1984 census. The 1984 census estimated the population of Dawachefa as 80,443,Antsokiya Gemza as 47,997 and Artuma Fursi as 51,672(Table2).Thus, based on these census the population of the study area was also projected up to 2015.

Table 2. Projected population of the study area (1984-2015)

Years	Projected total population		
	Dawachefa	Antsokiya Gemza	Artuma Fursi
1980	73,940	43,841	47,495
1984	80,443	47,697	51,672
1987	86,054	51,024	55,277
1990	92,057	54,583	59,133
1994	100,152	59,383	64333
1996	105,347	62,464	67670
2000	114,611	67,958	71181
2005	126,810	75,191	78757
2007	133,388	79,091	82842
2010	142,692	84,608	88621
2013	152,646	90,510	94802
2015	160,564	95,205	99717

(Source CSA, 1984)

3.2 Methods

3.2.1 Data and source of data

3.2.1.1 Satellite imageries

In order to analyze the spatio-temporal change of wetlands in the study area, Land sat imagery of 1984 (TM), 1993 (TM), 2000(TM), and 2013(TM) freely down loaded from United States geological survey (USGS) website. These data were used to produce the historical land-use/land-cover maps of the study area and wetland changes monitoring and mapping in particular. Source and acquisition date of these data are given in Table3 as follows. The Aster Global DEM 30 m was used to map different landscape of the study area. Moreover, different ancillary data were collected from different organizations to supplement the GIS and remote sensing data.

Table 3.Satellite data and sources

Satellite images	Date of acquisition	Path	Row	Resolution	Sources	Application
Landsat4 Landsat5 Landsat7 Landsat7	03/04/ 1984 25/03/ 1993 22/03/ 2000 28/03/ 2013	168 168 168 168	53 53 53 53	30m 30m 30m 30m	USGS website	Map Land use/Land cover Map
ASTER DEM				30m	Aster Global DEM Website	Slope, Elevation, Aspect

3.2.1.2 Ancillary data source

Different secondary data were obtained from Central Statistics Agency of Ethiopia (Demography data), Meteorological Agency of Ethiopia (meteorological data), Soil map from Ministry of Water and Energy has been collected to assist this study. The Dawa Chefa Wereda boundary map and Ethiopian Administrative map was also obtained from Ethiopian mapping agency (EMA) and brought to Universal Transverse Mercator projection in zone 37.

Table4. Ancillary data sources

Data type	Data source
Population Data (1994 to 2014) and climate data (T^0 from 2004 to 2014 and rain fall from 1963 to 2014).	CSA, Ethiopian Meteorology Agency and Kombolcha Meteorology Agency
Soil map	Ministry of Water and Energy
Topographic Map (1992)	EMA
Socio-economic data	Reports and documents of the Woredas, and Interview and questionnaire.
Key informant Interview	Local Residents

3.2.1.3 Materials and software

To collect, organize and analyze the relevant data the following Materials and software were used.

1. ERDAS Imagine 9.2: used for image pre-processing, stacking single bands, supervised maximum likelihood classification of land classes and accuracy assessment of the classification.
2. ArcGIS 10: used for data analysis, management, and spatial referencing, geo-referencing and make layout for final mapping. Moreover, the study area delineation and clipping process will be operated by ArcGIS software. It was also used to compliment the display and processing of the data.
3. GPS (Garmin Marine GPS Receiver or GPS72H) has been used to collect ground control points (GCPs) used to conduct ground accuracy assessment.
4. Sony Digital camera (14.5 mega pixels) was used to capture wetland images and images of some economic effect of the wetland in the study area.

3.2.2 Data processing and analysis

In order to analyze the spatio temporal LULC changes of the study area Land sat 5/4 TM and Land sat 7 imageries of four systematically selected years of the last 30 years was downloaded from USGS Earth explorer website. Since the study was carried out under the frame work of Geographic Information System (GIS) and Remote Sensing (RS) environment, the image processing task was carried out using (Earth Resource Data Analysis System) ERDAS Imagine 9.2 software.

The application of GIS and RS enable to analyze, store and retrieve large amount of spatio-temporal data-base of the study area for the last 30 years for wetland change monitoring purpose. The availability of spatially consistent data sets that cover large areas with both high spatial detail and high temporal frequency makes the utilization of GIS and RS as the most effective tools. Therefore, attempt has been made in this study to analyze the spatio-temporal wetland change of Dawa Chefa area by integrating RS and GIS technique with other data sets for the year between 1984 and 2013.

Land cover map was prepared after the images have been downloaded, projected and stacked (pre-processed) to be displayed in ERDAS IMAGINE software interface. In this research nearest neighbor resampling procedure was used (Eq. 1). It was used to determine the digital values to place in the new pixel locations of the corrected output image. The resampling technique by:

K-NN………………………………………………………… (Eq.1)

Where k = the number of nearest neighbors on which the selection is based

NN = abbreviates nearest-neighbors.

The probability *pj* that the *j*th closest neighbor is resampled is then given by:

$$Pj = (1/j)/ \sum_{i=1}^{k} 1/i \quad \text{……………………………………….. (Eq. 2)}$$

(Lall and Sharma (1996)

Due to the fact that the collected multi-temporal satellite image (Land sat TM) cover a large area with a sensor spatial resolution of 30 meter for all the spectral bands except band six (thermal band) which is 60 and band 8 with 15 meter were omitted from the scene the remaining bands were stacked to get false color composite (FCC) image in ERDAS IMAGINE 9.2 software (Jensen, 2004). Moreover, the analysts have made an automated image enhancement and contrast adjustments to the subset images of the study area. The time span of this study covers 30 years (1984-2013) categorized into intervals of 1984, 1993, 2000 and 2013 respectively.

Image enhancement for better interpretation was done to display the image in RGB true color composite (band 3, 2, 1) and inclusion of two infrared channels (4, 5, 3). In the former band combination band 3, 2 and1 was applied for vegetated and non-vegetated land area, green vegetation and, soil and vegetation discrimination mapping respectively. Whereas the latter band combination used for Vegetation moisture discrimination and Soil moisture discrimination, delineation of water body and soil moisture discrimination and, vegetated and none vegetated and cultural/urban features mapping.

Visual interpretation of various environmental features of the study area was done based on the visual elements or characteristics of satellite image i.e. tone, texture, shape, Pattern, shadow, association and aspect of the features with the support of field verification of each land use land cover features. High resolution images (Google Earth Image), topographic map and aerial photograph (Appendix 8) were used to verify the LULC of the area. There are various steps and principals involved in mapping LULC from Satellite imageries. However, presenting all the principles and steps is futile rather the most important ones are dealt here (Figure7). The overall objective of image classification procedure is to automatically categorize all pixels in an image into land cover classes or themes (Lillesand *et al*., 2004). Image classification is, thus required to convert remote sensing data in to thematic data.

The present study used supervised classification techniques to categorize the images in to different land use/land cover categories. Supervised classification can be used to cluster pixels in data set into classes corresponding to user defined training classes. This classification method requires selecting training areas for use as the basis for classification. Supervised classifications require a prior knowledge of the scene area in order to provide the computer with unique training classes. In this method, the user defines the original pixels that contain similar spectral classes representing certain land cover class.

The Supervised Maximum Likelihood classifier algorism classification system was used, since it is the most common method in remote sensing image data analysis (Richards 1995). It identifies and locates land cover types by combining the previous personal experience, and fieldwork (Jensen 2005). This classifier considers not only the cluster centers but also the shape, size and orientation of the clusters. This was achieved by calculating statistical distance based on the mean values and covariance matrix of the clusters.

Maximum Likelihood (ML) is a supervised classification method derived from the Bayes theorem, which states that the a posteriori distribution P (i|x) is given by:

$P(i|x)=P(x|i)P(i)/P(x)$……………………………...Eq(1)

Where,

P (x|i) = Likelihood function

P(i) = a priori formation

x = a feature vector

$P(x)$ = probability x is observed and it is calculated by:

$$P(x) = \sum_{i=1}^{m} p(x)|i)p(i) \text{ ……………….. (Eq2)}$$

Where, M=numbers of classes

$P(x)$ = normalization constant to ensure $\sum_{i=1}^{m} p(i|x)$ *sums to one*

Therefore, Pixel **x** is assigned to class i by the rule:

x €i if $P(i|x) > P(j|x)$ for all $j \neq i$…………………Eq (3)

The analysis was started by defining and collecting training samples which have the same reflectance value using Signature editor tools and saving the signature to undertake the classification activity. The signatures from the image for classification were collected using the training sample. The digitized polygons of each sampled pixel collected using the AOI tools were brought to signature editor for classification. Then, the satellite imageries were classified in to classes of wetland, forest, bush land, urban area, farmland and grass lands (Table5).

The classification accuracy assessment has been performed using ground truth points collected by hand held GPS. In order to determine classification accuracy, it is necessary to determine if the output map meets, exceeds, or does not meet certain predetermined classification accuracy criteria. One of the most common and typical method used to assess classification accuracy is the use of an error matrix (sometimes called a confusion matrix or contingency table (Lille sand and Kiefer, 1994).

3.2.2.1 Land-use/Land-cover change detection

After converting remote sensing data in to thematic map, the next step is detecting LULCC. In order to assess temporal and spatial wetland change detection in the study area Land use/Land cover has been consecutively analyzed using datasets from remotely sensed land sat imageries (TM land sat 4 and 5) of 1984, 1993 and(TM Land sat 7) of 2000, and 2013). Because remote sensing provides a good source of data from which updated land use/cover information can be derived efficiently and economically in order to perform inventory and monitor changes effectively (Donnay *et al*., 2001). The imageries of each year was classified into class of wetland, urban, bush lands, grass lands, forest and farm lands using supervised image classification methods(Table5).Then area change between two consecutive study periods computed using the classified imageries with area extent There are varies techniques in Land use/ Land cover change detection. From these the most common one is post classification comparative analysis of independent produced classifications from different dates (map-to-map comparison) and image-to -image comparison (Zewudu).In the case of the post-classification method, imageries from different archives in different year interval are classified and labeled individually. In this particular research, Post-classification method has been employed to meet the predefined objectives. Hence, in post-classification technique the change is determined from independently classified land-use land cover classes from each of the dates under investigation.(Eastman, 1999).Moreover, following post classification, the absolute area change and relative change of each Land use/ Land cover change were calculated using ERDAS IMAGINE 9.2 software. To calculate the change of each LULC classes to other LULC classes, LULC change matrix was done. Tables were prepared for the change detection matrix that depicted the change of one LULC to the other one. The column of the table represents the final stage and the row represents the initial stage. In this regard image differencing was applied likewise from initial to final images. The negative change indicates a certain LULC is in a state of decrement while the positive value indicates increment. The diagonal values from cross tabulation matrix marked by dark gray color in tables indicated land-use/land-covers that were unchanged through the time interval under this study. This thematic change detection has been computed via deducting the area in hectare from classified imageries of 1984 from 1993, 1993 from 2000, 2000 from 2013 and 1984 from 2013.

Finally, absolute wetland change and its relative conversion to different LULC between 1984 and 2013 were discussed.

3.2.2.2 The spatio-temporal wetlands change between1984-2013

In order to assess temporal and spatial wetland change detection in the study area, Land use/Land cover was successively analyzed using datasets from remotely sensed land sat imageries (TM land sat 4 and 5) of 1984, 1993, 2000, and 2013.After analyzing the LULC changes of the four years (1984, 1993, 2000 and 2013) by using GIS analysis (matrix), post classification comparative analysis between each consecutive(successive) years and the beginning and the end years of the study was used to assess spatio-temporal wetlands changes. This was done by extracting the total wetlands change between two successive years to other LULC classes. Finally, the wetlands was systematically extracted from classified imageries to map the spatio-temporal change occurred in the last 30 years.

3.2.2.3 Responsible factors for wetland changes of Dawa Chefa area

By comparing the different magnitude of change of wetlands in to other LULC classes, the researcher identified the major driving forces of wetland change.

Table 5.Description of LULC classes used for analysis ofchanges1984, 1993, 2000 and 2013

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LULC classes	Description
Wetlands	Areas where the water level is permanently or temporarily at (or very near) the land surface, typically covered in either herbaceous or woody vegetation cover.
Urban/built up	Areas where there is a permanent concentration of people, buildings, and other man-made structures and other activities.
Bush/shrub land	Land covered by an open stand of trees/or-scattered shrubs 2 to 5m tall and canopy cover of more than 20% as well as short shrubs and thorny bushes with little useful woods found along rugged micro-relief.
Forest area	Areas covered by trees forming closed or nearly closed canopies (70-100%)
Grass land	Areas with permanent grass cover along ridges steep slopes and plain areas used for grazing; usually private as well as communal.
Farmland	Contiguous areas used for rain fed and irrigated cultivation, including fallow plots, cultivated land mixed with some bushes, trees and rural homesteads but dominated by farmland.

(Source: (Girma, 2003)).

In addition to the data acquired from satellite imagery, ancillary data were collected to fill information gap in the image analysis. Firstly, preliminary field survey was conducted so as to get general view on the physical condition of the area comprised of wetland cover, land use type, and topography of the area. Relevant information about the responsible factors of wetland change was collected through focus discussion and interviewing-pastoralists, farmers and key informants. Finally secondary data were collected from reports and documents of Irrigation development office, agriculture office, NGOs' (World vision) of the Dawa Chefa Wereda and Zone of Oromia Liyu Zone, and other related published and unpublished documents.

3.2.2.4 The socio-economic effects of wetland change in Dawa Chefa area.

To analyze the socio-economic effect of wetland change primary data were collected based on gender, age, position, family size, educational level, religion, marital status, occupation, estimated monthly income, land holding size and cattle holding size. Five enumerators were appointed for primary data collection. Intensive training was given on how to collect data. The data collection was conducted from April 14 to May 4, 2014. The secondary data were collected from different reports of government authorities (zonal, Wereda and city offices), journals, thesis, published and unpublished documents from relevant organizations.

A structured questionnaire was prepared to collect the necessary primary data. The structured questionnaire was first prepared in English and translated in to the Zonal language Oromifa for practical field work. Finally, the questionnaires were applied through interview for the samples of four Kebeles. The kebeles which are Gerbi, Kelo, Shekla and Woledi villages were selected purposively for the study, because the villages are close to the wetland and have road accessibility. Then from each site 40 sample respondents were selected randomly.

The quantitative and qualitative data collected through questionnaire, interview, field observation and secondary data were sorted organized and analyzed on descriptive statistics using tables, graphs, pie charts and figures.

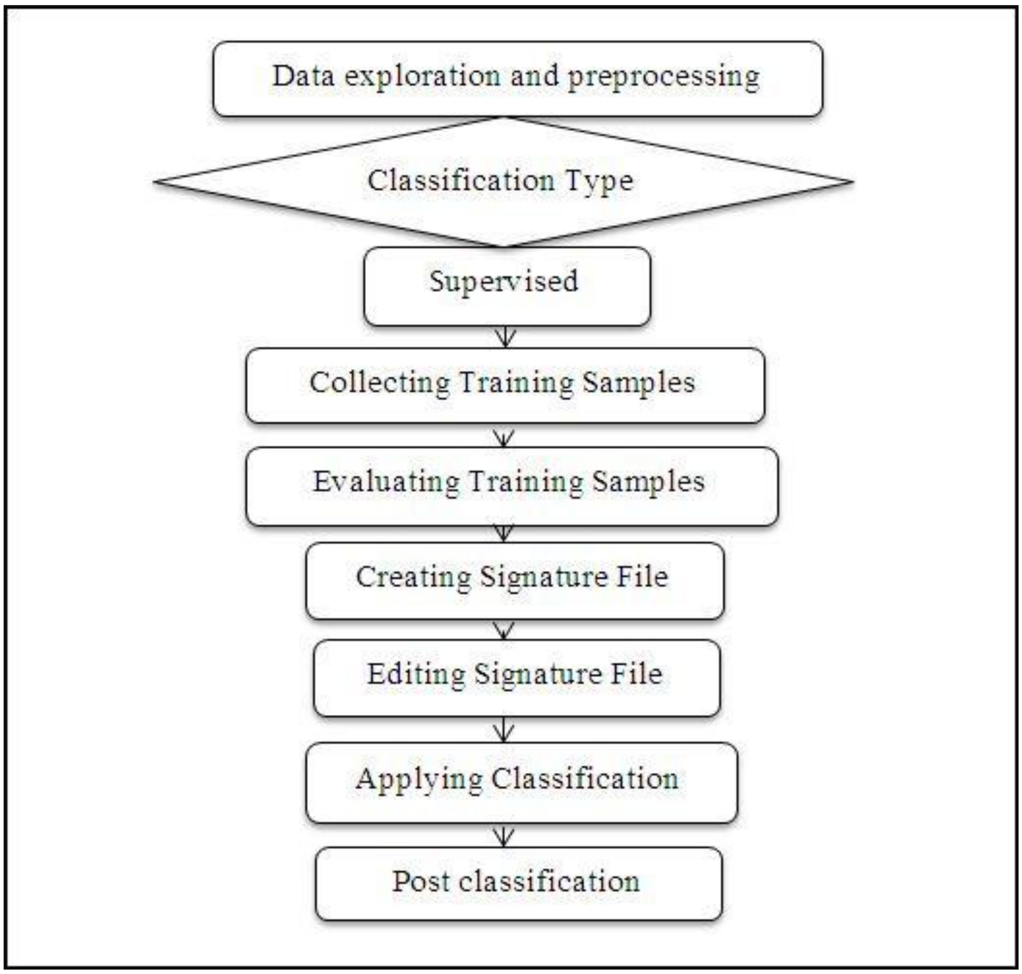

Figure 7. Flow chart of image classification

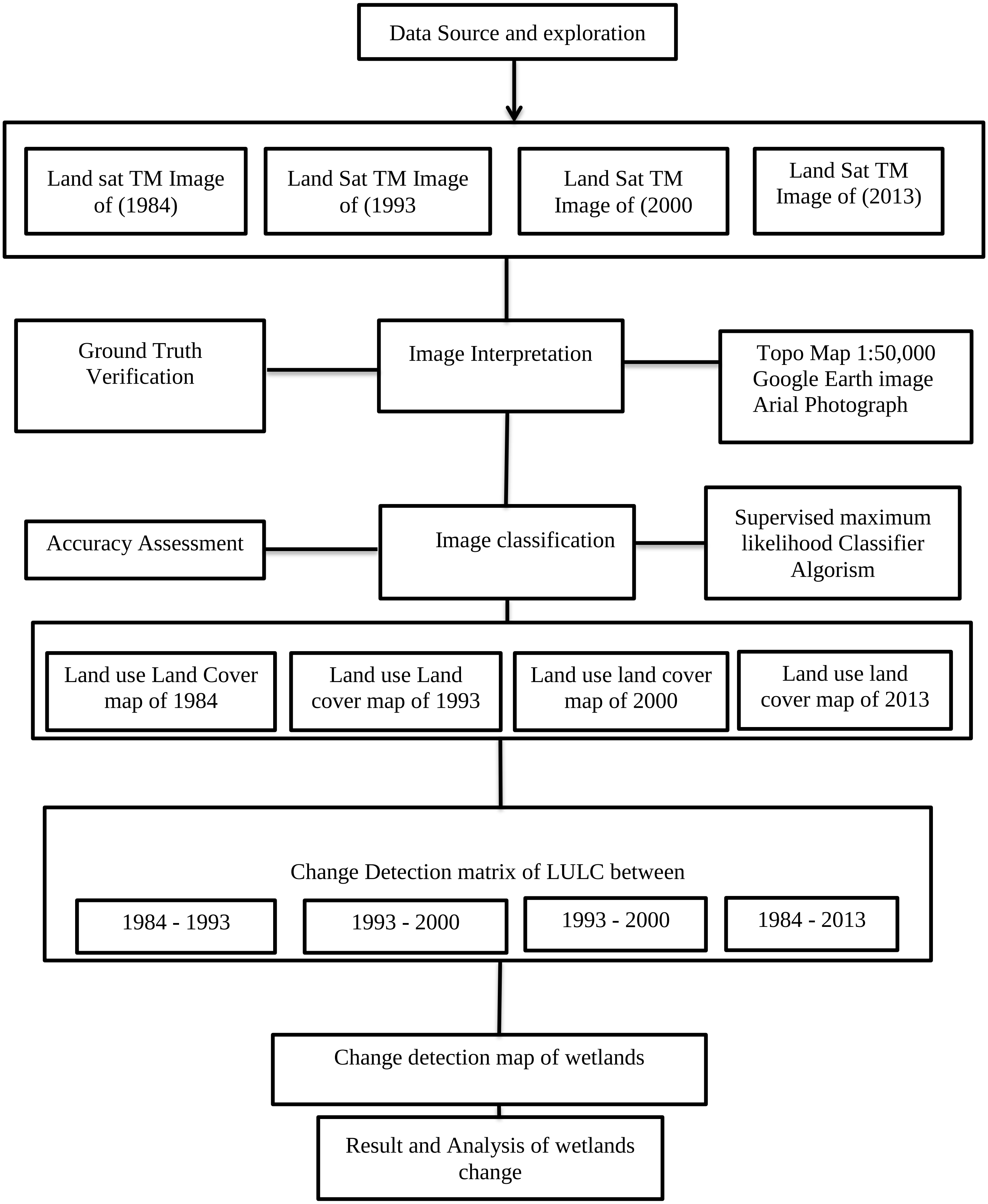

Figure 8.Flow chart of wetland change mapping

3.2.3 Accuracy assessment for image classification

Following classification process the accuracy assessment of each land-cover/land-use has been conducted to assure the classification result was accurate for further use. Accuracy assessment is a process used to estimate the accuracy of image classification by comparing the classified map with a reference map (Caetano *et al.,* 2005). Currently, accuracy assessment is considered as an integral part of any image classification process because of the fact that image classification using different classification algorithms may classify pixels or group of pixels to wrong classes. The common way to represent classification accuracy is in the form of an error matrix. Using error matrix to represent accuracy is recommended and adopted as the standard reporting convention (Congalton, 1991).

Table 6.Over all accuracy statistics for the Land use land cover classifications

Accuracy statics of	1984	1993	2000	2013
Overall classification accuracy **(%)**	80.66	83.43	81.23	85.33

Table 7.Producer's and user's classification accuracy statics of land use land cover classes (1984-2013)

Class name	1984 Accuracy (%)		1993 Accuracy (%)		2000 Accuracy (%)		2013 Accuracy (%)	
	Producers	Users	Producers	Users	Producers	Users	Producers	Users
Wetland	77.37	89.47	89.47	94.44	88.00	79.00	90.00	86.32
Urban	88.23	75.00	92.86	68.42	88.00	77.00	95.56	90.00
Bush land	90.91	83.33	72.73	88.89	86.00	81.23	88.88	85.00
Forest	71.43	83.33	70.00	87.50	88.00	66.43	79.45	80.00
Grass	66.66	66.66	83.33	83.33	83.00	78.00	84.00	73.00
Farmland	85.00	75.00	88.00	66.000	91.00	85.00	76.00	84.00

The results of overall classification accuracies scored were 80.66 %, 83.43%, 81.23% and 85.33 % respectively for the classified Land sat images imageries 1984, 1993, 2000 and 2013 respectively (Table 6).The LULC change statistics has been performed using relative change detraction mechanism. This technique had enabled as evaluate the area extent and percentage change of one land use/Land cover to others and to determine their spatial increase or decrease in different time interval due to natural and manmade factors. For this specific purpose the thematic change matrix analysis of each land-use/land-cover for the study periods categorized into four phases from 1984 to 1993, 1993 to 2000, 2000 to 2013 and from 1984 to 2013 has been computed using ERDAS EMAGINE 9.2 software.

Chapter 4: Results and Discussion

4.2. Results

4.2.1. Land use/Land cover change detection

4.2.1.1 Land use/ Land cover in 1984

Table 8 and figure 9 shows that land use/ land cover (LULC) of the study area in quantity and thematic map respectively (Table 8 and Figure 9). In this year forest and bush land cover were the highest coverage of the total area of the study area. Each of them constituted relatively larger proportions which was 83697.84 ha (33.46%) and 83800.53 ha (33.5%) of the total area respectively. Besides, a relatively considerable amount of the area was covered by farmland 33,975.72ha (13.6 %), grass land 29012.67ha (11.6%) and wetland 18603.63 ha (7.4%). In this year built up area covered the smallest share of the total area which was 1084.86ha (0.43%) (Table8). These conditions were considered as a baseline for change detection over the study years.

Table 8. Absolute area and percentage coverage of LULC (1984)

S/N	Land use and land cover of 1984		
	Class Name	Area in hectare	Area %
1	Wetland	18603.63	7.44
2	Urban	1084.86	0.43
3	Bush land	83800.53	33.5
4	Forest	83697.84	33.46
5	Grass	29012.67	11.6
6	Farmland	33975.72	13.6
	Total	250175	100

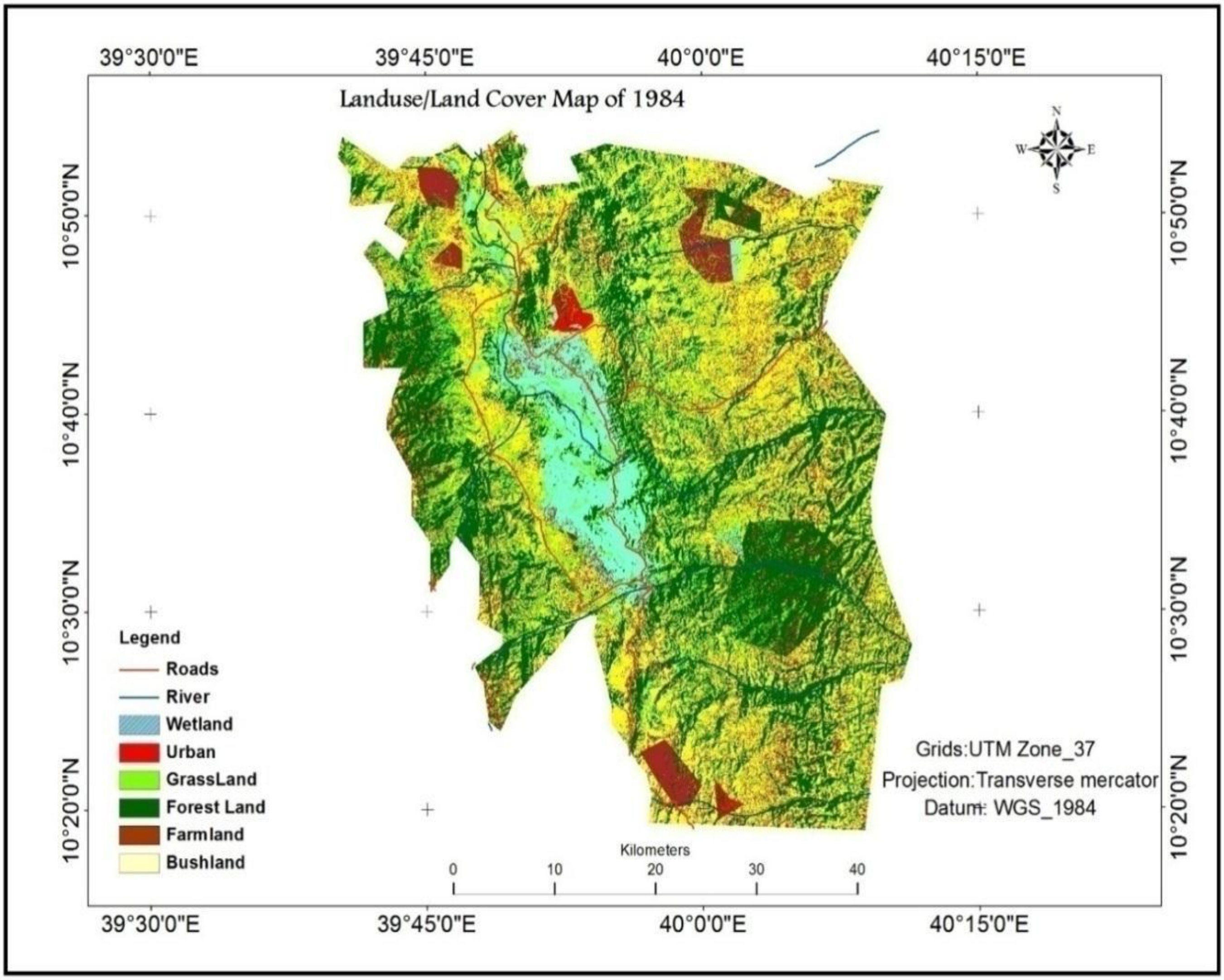

Figure 9. Land use land cover map of the study area in 1984

4.2.1.2 Land use land cover in 1993

In this year after 9 years (in 1993), the land use land cover classes that covered the highest share of total area were forest and bush like that of in 1984. The shares of forest and bush land coverage were 30.29% and 33.33% respectively. Wetlands, farmlands and grass lands constituted 6.41%, 17.62% and 11.65% of the total land area in 1993 respectively. Urban land area coverage still the smallest one which was 0.7%. However, when it was compared with that of 1984 LULC, the study area has undergone significant modifications and conversions in this study year. Because wetlands and forestlands were changed in to other LULC classes. About 1.01% and 3.21% of total area of wetlands and forests respectively changed in to other LULC classes (Table9). On the other hand, farm land, urban land and grasslands increased by 4.02%, 0.33% and 0.05% from 1984 to 1993 respectively. In general, in this year forest and wetlands showed considerable decrease while farm and urban land showed increment compared to the LULC setting of 1984.

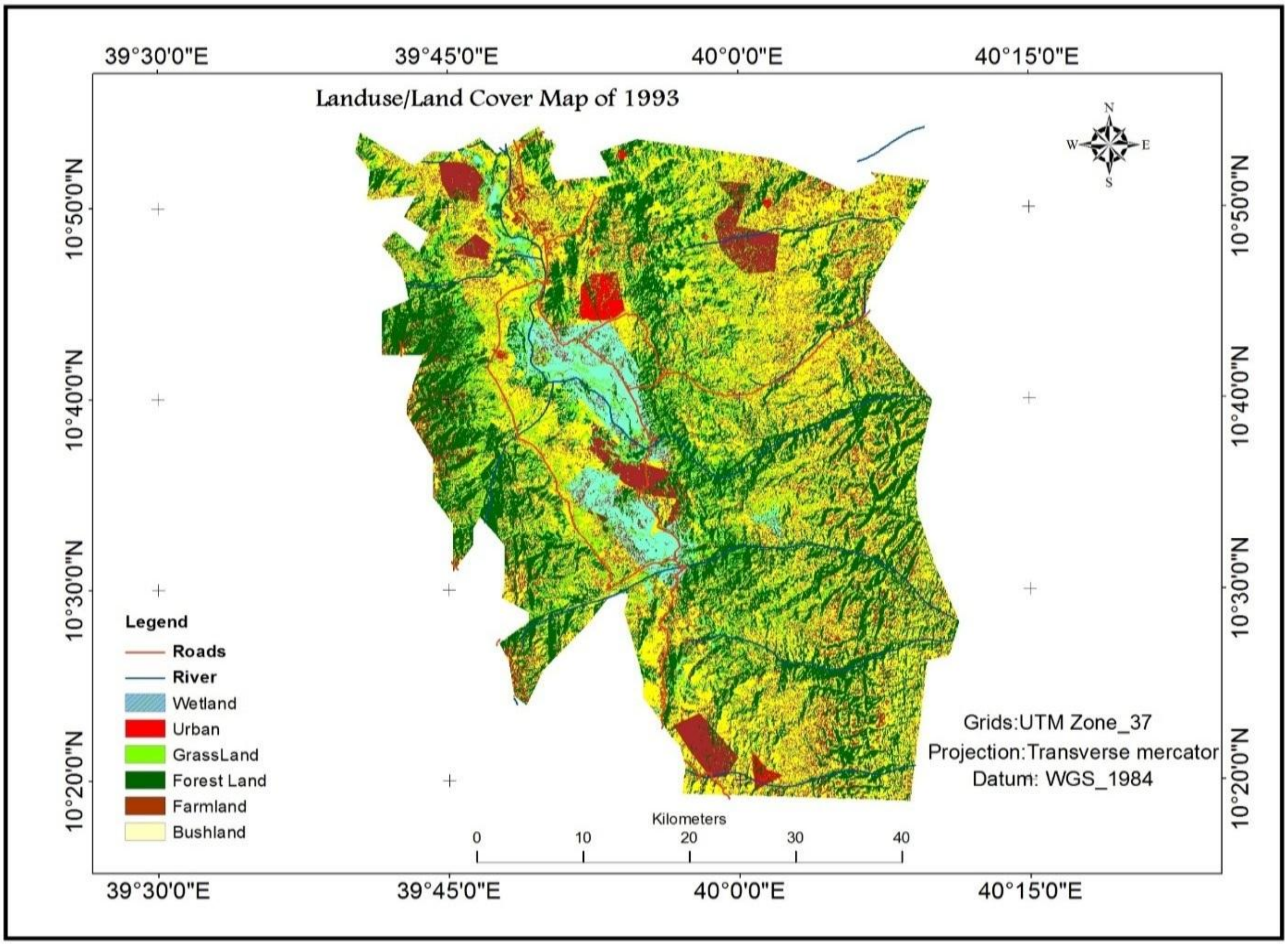

Figure 10.Land use land cover map of 1993

Table 9.Absolute area and percentage coverage of LULC (1993)

Land use Land cover of 1993			
S/N	Class Name	Area in hectare	Area Δ in %
1	Wetland	16052.31	6.41
2	Urban	1753.29	0.7
3	Bush land	83381.13	33.33
4	Forest	75772.62	30.29
5	Grass	29146.5	11.65
6	Farmland	44069.4	17.62
	Total	250175.25	100

4.2.1.3 Land use land cover in 2000

After 16 years (in 2000) farmland, bush land, and forest land constituted the highest share of total area coverage. Each covered 27.4%, 27.2%, and 24.1% of the total area in this year respectively. Grassland, wetlands and urban areas covered the remaining part of the area by 15.2%, 5.1% and1.2% of coverage respectively. But, in this study year farmland, grass land and urban dramatically increased to 27.4%, 15.2% and 1.2% respectively. Here farmland took over the place of forest land in extent of area coverage. On the other hand, the wetland and forest decreased from 6.41% and 30.29% in to 5.1% and 24.1% (Table10).The change in the second study period (1993-2000) was much significant compared with the first one(1984-1993).

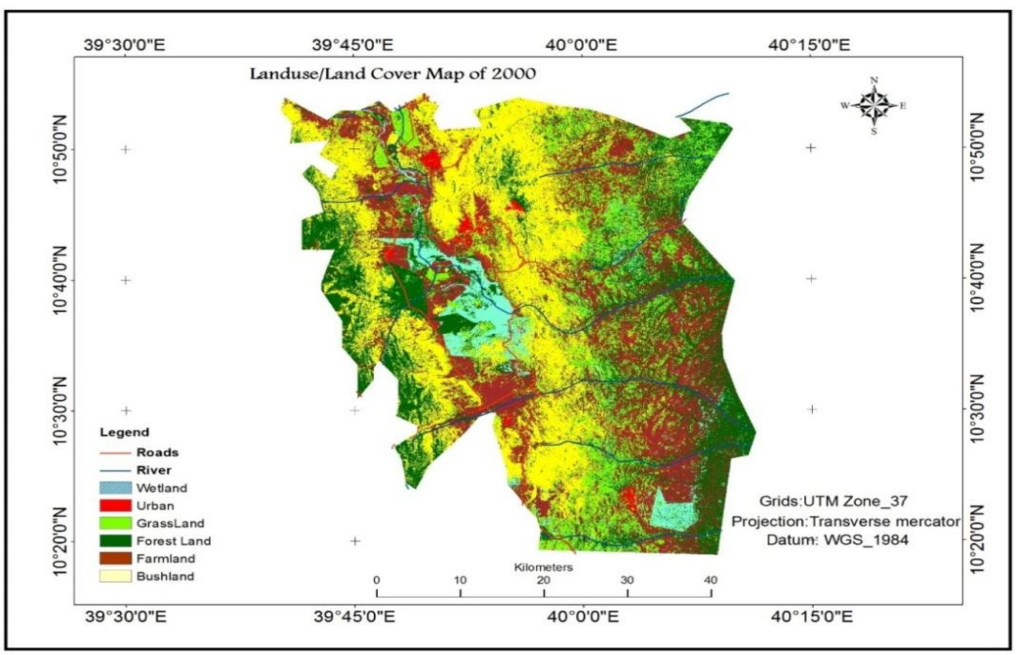

Figure 11.LULC map of the study area in 2000

Table 10Absolute area and percentage coverage of LULC (2000)

S/N	Land use Land cover of 2000		
	Class Name	Area(hectare)	Area in%
1	Wetland	12,713.04	5.1
2	Urban	2966.94	1.2
3	Bush land	68422.68	27.2
4	Forest	60225.21	24.1
5	Grass	38134.08	15.2
6	Farmland	68841.18	27.4
	Total	250175.25	100

4.2.1.4 Land use land cover in 2013

After 30 years the LULC mosaic of the study area dramatically changed. Farmland and bush land area constituted more than half of the total area of LULC arrangement. In this year 28.2% and 32.9% of the total area of Dawa Chefa area were covered by farm and bush land respectively. The remaining portion of the area was covered by 24%, 10.9%, 2.6% and 1.4% of grass, forest, wetland and urban lands respectively. This year was the year at which considerable LULC change dynamics was experienced in the study area. Wetland and forest severely declined to 2.6% and 10.9% respectively (Table11). By this year (2013) wetlands showed the highest declination of area extent of all the other study years. On the contrary, farmland and urban area increased to 28.2% and 1.4% respectively (Table11). Although the area coverage share of urban looked small; it showed the highest rate of increment followed by farmlands.

Wetlands and forest LULC classes showed dramatically decrease. About12, 207.06ha (65.62%) of wetland and 56,350.53ha (67.33%) of forest were changed in to other LULC classes over these thirty years. On the other hand, farmland and urban area increased by 36596.4ha (107.7%) and 2488.32ha (229.37%).The accelerated increment of cultivation land and urban area at the expense of other LULCs was attributed to the alarming rate growth of population in the area.

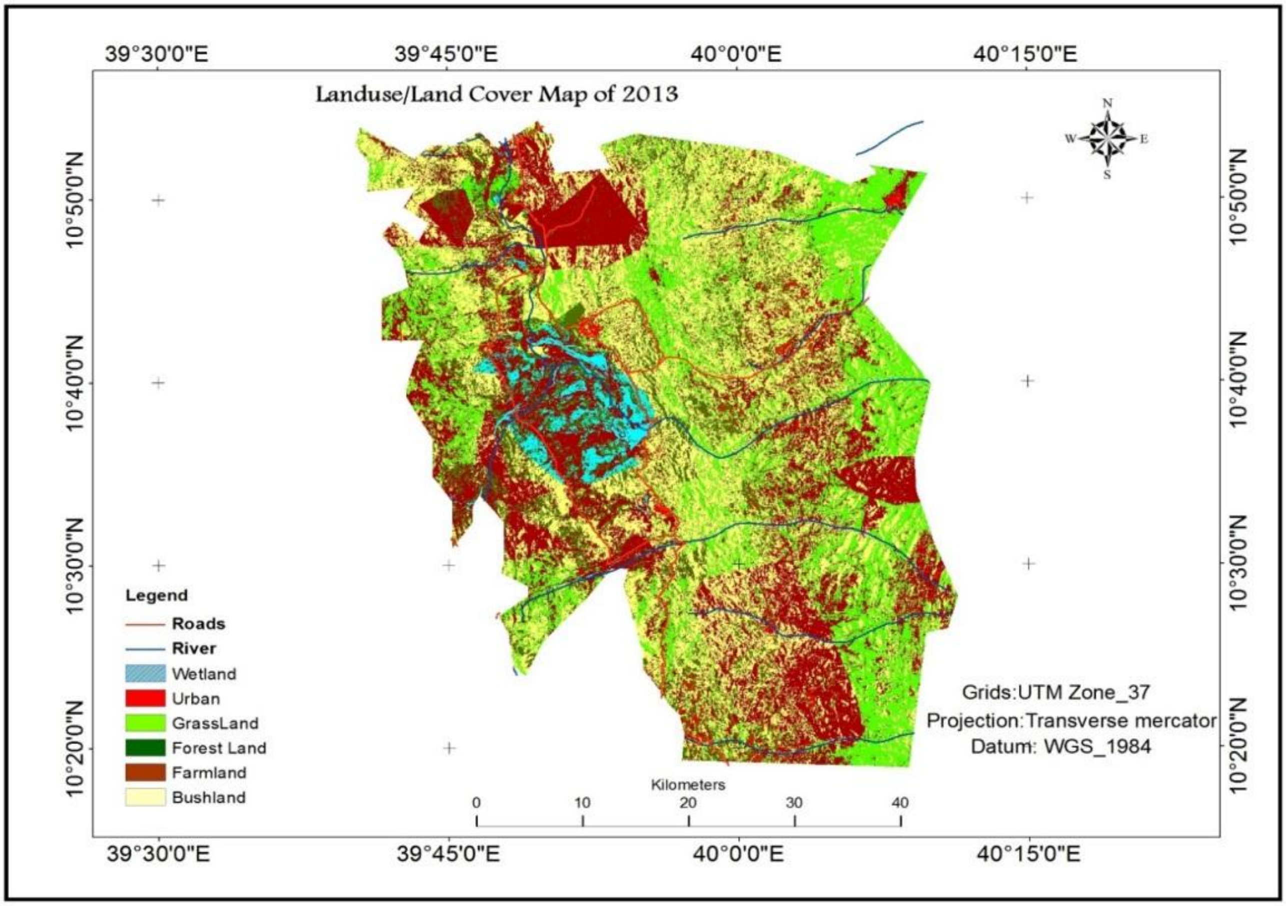

Figure 12.Land use land cover map of the study area in 2013

Table 11.Absolute area coverage of Land use land cover in 2013

	Land use Land cover of2013		
S/N	Class Name	Area in hectare	Area in %
1	Wetland	6396.57	2.6
2	Urban	3573.18	1.4
3	Bush Land	82287.36	32.9
4	Forest	27347.31	10.9
5	Grass	59998.68	24
6	Farmland	70572.15	28.2
	Total	250175.25	100

4.2.1.5 Land use/Land covers change between 1984 and1993

The LULC in the study area have undergone significant modifications and conversions in the course of the study years (Table16). In (1993) after 9 years, the farm land dramatically increased in to 17.62 % whereas wetland decreased in to 6.4%. In this year only farmland and urban showed increment while the other has experienced a relatively small decline. Relatively the change in the area coverage of the different LULC classes during this period was slow (Figure 10); though there was a continuous dynamics among them (Table16).Between 1984 and 1993 forest and wetland changed in to other LULC classes. About 2551.32ha (13.741%) and 7925.22ha (9.5%) of total area of wetlands and forests respectively changed in to other LULC classes (Table17). Out of 2551.32ha area of wetlands, 1761.66ha, 424.3ha, 341.5ha and 24.12 ha were changed in to farmland, urban area, grassland and forest respectively (Table12).Concerning forest from 7925.22ha area of forest the highest proportion which was 7832.97 were changed in to farmland area. The remaining 983.07ha and 1.98ha were changed in to bush land and urban lands respectively (Table12).

Table 12.Land use land cover change matrix between1984 and 1993

	Class Name	1993							
		Wetland	Urban	Bush Land	Forest	Grass	Farm	Row Total	Class change
	Wetland	16052.13	424.26	0	24.12	341.46	1761.66	18603.63	2551.5
	Urban	0.18	1084.68	0	0	0	0	1084.86	0.18
1984	Bush Land	0	85.14	82398.1	868.68	0	448.65	83800.57	1402.47
	Forest	0	1.98	983.07	74879.8	0	7832.97	83697.82	8818.02
	Grass	0	157.23	0	0	28805.04	50.4	29012.67	207.6
	Farmland	0	0	0	0	0	33975.7	33975.7	0
	column Total	16052.31	1753.29	83381.17	75772.6	29146.5	44069.38	250175	12979.8
	Class change	0.18	664.61	983.07	892.8	341.46	10093.68		

4.2.1.6 Land use land cover change between 1993 and 2000

After 16 years (in 2000), farmland, grass land and urban dramatically increased to 27.4%, 15.2% and 1.2% respectively. On the other hand, the wetland and forest decreased in to 5.1% and 24.1% (Table16).The change in the second period (1993-2000) was much significant compared with the first(1984-1993). The land use land cover change matrix between 1993 and 2000 showed that during the indicated period there was a significant land use/land cover dynamics. About 3432.06ha, 2720.34ha, 2439.09ha and 385.74ha of the wetlands were converted in to farmland, forest, grassland, bush land and urban areas respectively. With regard to forest 2337.47ha, 23194ha and23194.4ha of forest area was converted in to farmland, urban area and bush land respectively (Table13).In general total net area of wetlands, bush and forest showed decrement while farmland, urban areas and grass lands showed increment between1993 and 2000.

Table 13.Land use land cover changes matrix between 1993 and 2000

	Class Name	2000							
		Wetland	Urban	Bush Land	Forest	Grass	Farmland	Row Total	Class change
1993	Wetland	5053.14	385.74	2021.94	2720.34	2439.09	3432.06	16052.31	10999.2
	Urban	9.81	370.53	365.49	105.39	387	515.07	1753.29	1382.75
	Bush	3060.99	1079.73	17511.5	20780.9	17957.8	22990.2	83381.12	65869.6
	Forest	1679.22	23194.4	23194.4	23005.5	4097.79	23374.7	98546	75540.5
	Grass	1370.52	273.51	13442	4474.08	4203.9	5382.54	29148.4	24942.5
	Farmland	1539.36	432.99	11411.6	8767.89	8836.56	13081.1	44069.5	30988.5
	column Total	12713.04	25736.9	67946.9	59854.1	37922.2	68775.67	272948.8	209722.9
	Class change	7659.9	25366.37	50435.4	36848.6	33718.3	55694.6		

4.2.1.7 Land use/ Land cover change between 2000 and2013

In this year study year wetland and forest severely declined to 2.6% and 10.9% respectively (Table16). Between 2000 and 2013 wetlands showed the highest declination of all the other previous study years. On the contrary, farmland and urban area increased to 28.2% and 1.4% respectively (Table16).The LULC change matrix between 2000 and 2013 showed the change dynamics that 4730.76ha, 2190.78ha, 2097.54ha and780.39ha of wetland were converted in to farmland, bush, forest and urban areas respectively. Similarly, 19420.83ha, 19844.01ha, 1629.27ha and1100ha of forest were changed in to farmland, grassland, wetland and urban area respectively (Table14).

Although the net increment of total area of farmland and urban areas were high, considerable amount of area of farmland and urban were changed in to other LULC systems. About21083.04ha, 14,244.3ha, 4,151.16ha, 1,046.34ha and 508.23ha area of farmland were changed in to grass, bush, forest, wetland and urban areas respectively (Table14).In general, only wetland and forest dramatically decreased in the period between 2000 and 2013.In contrary, grass land and urban area showed significant increment. The other LULC classes showed relatively small increment.

Table 14.land use land cover change matrix between 2000 and 2013

	Class Name	2013							
		Wetland	Urban	Bush Land	Forest	Grass	Farmland	Row Total	Class change
2000	Wetland	2129.85	780.39	2190.78	2097.54	783.72	4730.76	12713.04	11363.54
	Urban	31.59	239.22	815.04	326.79	310.95	1239.84	2963.43	2724.21
	Bush Land	828.72	240.48	32083.2	9717.75	13326.66	11750.04	67946.65	35863.65
	Forest	1629.27	1100.7	13138.29	4721.04	19844.01	19420.83	59854.14	55133.1
	Grass	730.8	704.16	19815.75	6333.03	4650.3	5688.09	37922.13	33271.83
	Farmland	1046.34	508.23	14244.3	4151.16	21083.04	27742.59	68775.66	41033.0
	column Total	6396.57	3572.97	82287.4	27347.3	59998.68	70572.15	250175.1	179389.3
	Class change	4266.72	3333.96	50204.16	22626.27	55348.38	42829.6		

4.2.1.8 Land use/ Land cover change between 1984 and2013

After three decades (in 2013), the LULC in the study area has undergone fast dynamics which was reflected in the exchange of area coverage between LULC classes. In the overall study period wetlands and forest lands showed continuous reduction while farmland and urban showed continuous increment. Wetlands alarmingly decreased from 18603.63ha (7.4%) in the beginning of the study year (1984) to 6390.57ha (2.6%) in the end of the study year (2013). This is severe change in the LULCC dynamics. Similarly, forest areas decreased from 83,697.84ha (33.5%) in 1984 to 27347.3ha (10.9%) in 2013.

On the other hand, farmland and urban areas increased from33975.72ha (13.6%) and 1084.86ha (0.4%) in 1984 to 70572.15ha (28.2%) and 3573ha (1.4%) in 2013 respectively (Table16).The change of wetland to other LULC classes was not consistent among the LULC classes to which wetland was changed in to (Table15). For instance from 1984 to 1993 wetland was not changed in to bush land cover (Table12). The LULC change matrix between 1984 and 2013 showed that 5270ha, 5389.2ha, 3516.03ha and 485.73ha were changed in to farmland, bush land forest land and urban area respectively. Similarly, 1233.36ha, 27134.27ha and31967.3ha of forest were changed in to wetlands, farmlands and grasslands respectively (Table15).

Wetland and forest have got decrement in the course of the study years. Throughout the course of the study years farm land took the greatest share of area which was changed from wetland. Despite small in area, urban experienced the highest magnitude of positive change. The wetland, forest and shrub land had been converted to urban built-up, farm land and grass lands between 1984 and 2013(Table15). On the other hand, from the identified LULC change matrix between 1984 and 2013 the rate of coverage increase of urban or built-up area accounted for 2488.32 ha (229.37%) from the total area of urban in 1984.(Table17). The change of agriculture was increased by 36596.43 ha (107.7 % in the periods under this research i.e. between1984 and 2013(Table17).

Table 15 Land use land cover change matrix between 1984 and 2013

	Class Name	2013							
		Wetland	Urban	Bush Land	Forest	Grass	Farmland	Row Total	Class change
1984	Wetland	2964.6	485.73	5389.2	3516.03	977.31	5270.76	18603.63	15639
	Urban	0	31.41	589.59	173.97	147.96	141.93	1084.86	1053.5
	Bush Land	882.09	1779.39	30849.57	10009.1	17257.23	23023.17	83800.55	52951
	Forest	1233.36	233.1	16802.82	6226.92	31967.37	27234.27	83697.84	77471
	Grass	1010.88	153.18	13548.24	3638.79	4383.18	6278.4	29012.67	24629.5
	Farmland	305.64	890.37	15107.94	3782.52	5265.63	8623.62	33975.72	25352
	column Total	6396.57	3573.18	82287.36	27347.33	59998.4	70572.15	250175.24	197126
	class change	3432	3541.8	51437.8	21120.4	55615.5	61948.5	197096	

Table 16.Land use land cover and their extent between 1984 and 2013

LU/LC Class	1984		1993		2000		2013	
	Area in hectare	Area %	Area in hectare	Area %	Area in hectare	Area %	Area in hectare	Area %
Wetland	18603.63	7.4	16052.31	6.41	12,713.04	5.1	6396.57	2.6
Urban	1084.86	0.4	1753.29	0.7	2966.94	1.2	3573.18	1.4
Bush Land	83800.53	33.5	83381.13	33.33	68422.68	27.2	82287.36	32.9
Forest	83697.84	33.5	75772.62	30.29	60225.21	24.1	27347.31	10.9
Grass	29012.67	11.6	29146.5	11.65	38134.08	15.2	59998.68	24
Farmland	33975.72	13.6	44069.4	17.62	68841.18	27.4	70572.15	28.2

4.2.2 Spatio- temporal changes of wetlands

Before 30 years the land cover share of wetland was 18603.63ha. But after 30 years the land cover share of wetlands radically decreased to 6396.57ha (Figure14 and table 16).The results of image analysis showed that the magnitude of decrement of wetlands increased since the beginning of the study year (1984) to the end of the study year (2013).The rate of change of wetlands to other LULC classes were 283.48ha per year between 1984 and 1993, 477.8ha per year between 1993 and 2000, 485.9ha per year between 2000 and 2013, and 406.9ha per year between 1984 and 2013.The highest rate was recorded between 2000 and 2013(Appendix4).

The area of wetlands and forest was negatively declined in large scale between1984 and 1993 in time and resulted the reduction of -12207.06 ha (- 65.62 %) and -56350.53 ha (- 67.33 %) in area extent respectively and followed by bush land -1513.17(-1.8%) (Table17). The magnitude of change of wetland loss of Dawa Chefa area increased in space and time (Table17, Figure13 and Figure14). Consequently, the wetland decreased at amount of -2,551.32ha, -3,339.27ha, -6,316.47ha, and -12207.06ha from 1984 to 1993, 1993 to 2000, 2000 to 2013 and 1984 to 2013 respectively (Table17).Figure14 depicts that he spatial extent at which the wetlands shrank through time. In general, the extent of wetlands that was lost in the last 30 years was found to be 12,207.06ha.This was 65.6% of the total wetlands area that was existed in 1984(table17).Therefore, this research detected that the extent of Dawa Chefa wetlands area decreased severely through time (Figure14 and Figure19).

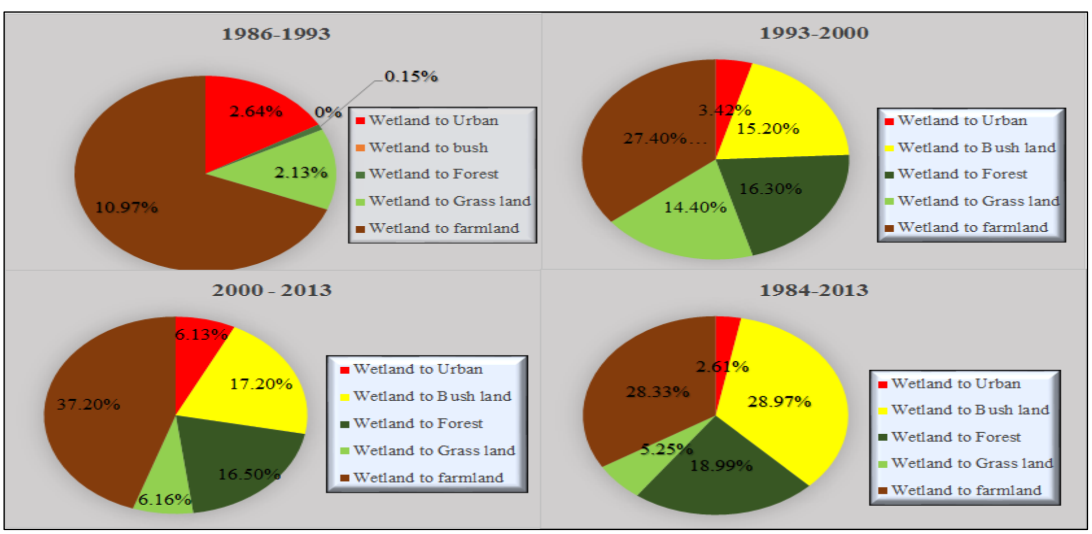

Figure 13.Wetlands conversion to other land use land cover.

Table 17.Spatio temporal change of wetlands between 1984 and 2013

LU/LC Type	Spatio-temporal change magnitude of LULC change in (hectare) and Percent (%)							
	1984 - 1993		1993 – 2000		2000 -2013		1984-2013	
	Area(ha)	Area %	Area(ha)	Area %	Area (ha)	Area %	Area (ha)	Area %
Wetland	-2,551.32	13.741	-3,339.27	-20.802	-6,316.47	-49.685	-12207.06	- 65.62
Urban	668.43	61.614	1213.65	69.221	606.24	20.433	2488.32	229.37
Bush	-419.4	-0.5	-14,958.45	-0.179	13,864.68	0.203	-1513.17	- 1.8
Forest	-7,925.22	-9.469	-15,547.41	-20.519	-32,877.9	-54.592	-56350.53	- 67.33
Grass	133.83	0.461	8,987.58	30.836	21,864.6	57.336	30986.01	106.8
Farmland	10,093.68	29.71	24,771.78	56.211	17,30.97	2.514	36596.43	107.7

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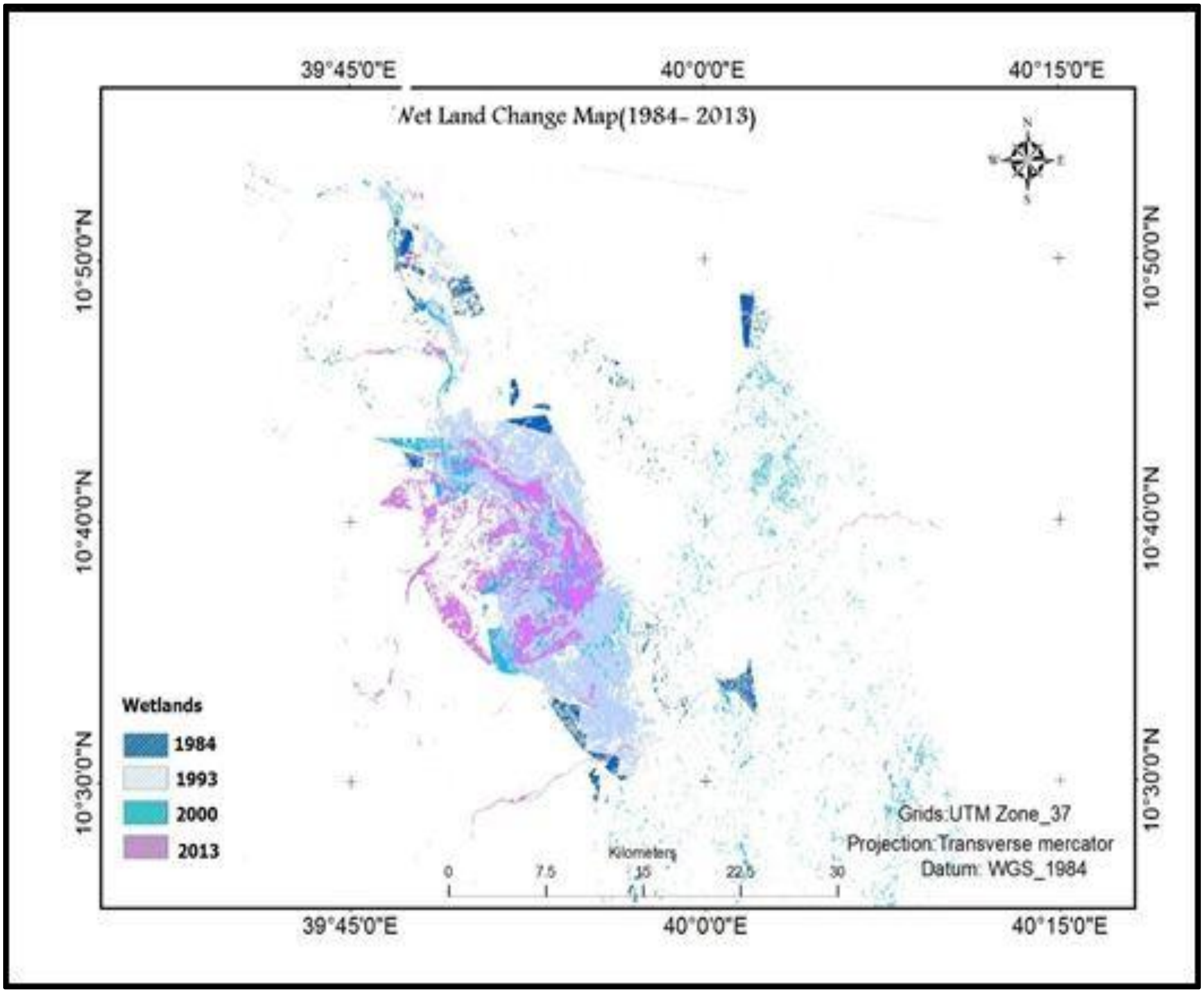

Figure 14.Wetland change detection map (1984 to 2013)

4.2.3 Driving forces of wetland change

The LULC change matrix of the study area showed that the wetland of Dawa Chefa area changed in to other LULC classes in the last 30 years. However, the change or conversions of wetlands to other LULC classes were not consistent. Throughout the course of the study year much of the wetlands changed into farmland (Figure13).The LULCC matrix between 1984 and 1993 depict about1761.6ha and 424.26ha wetlands were changed into farmland and urban area respectively. In the second phase of the study year (1993 to 2000) the matrix presented that 3432.06ha, 2720.34ha, 2439ha and 385.74ha of wetlands were converted in to farmland, forest, grasslands and urban area.

In the last phase of the study years from 2000 to 2013 and 1984 to 2013, 4730.76ha and 5270ha of wetlands were converted in to farmland respectively (Table14 andTable15). All these indicated that farmland expansion and related activities have damaged the wetlands. Farmland LULC of the area is the leading one to which wetland was changed. Because image analysis showed that 10%, 21.4%, 37.2% and 28.33% of the wetland area changed in to farmland from 1984 to 1993, 1993 to 2000, 2000 to 2013 and 1984 to 2013 respectively. Therefore, population pressure is the major factor for the expansion of farmland which resulted in loss of wetland.

Furthermore, there were several factors raised by key informants for wetland changes of Kemissie area. About 91.3%,93.8%,95.6%,88.8% and 87.5% of the respondents put population pressure, farmland expansion, waste dumping, overgrazing and sedimentation were the major factors of the decrement of the wetlands respectively(Table20) and (Appendix 3).Thus, it is found that population pressure which was the factor for wetland loss was being the mother of other factors such as village establishment and expansion, farmland expansion, urbanization, road construction and intensive grazing practice which in turn the major factors for wetland loss of the study area (Appendix.3).

According to information from elders of the community, key informant groups and focus discussion, the size of households' increases at increasing rate from time to time. In order to get land for settlement, farm and grazing the local community has been using different mechanisms such as water diversion, and dumping to shrink the swampy, marshy and wet areas. Areas that were inundated are now converted to village (Figure15).Nomads construct temporary houses around the wetlands by the mangrove called Filla (Figure15). They used this house only for winter seasons. When the summer comes they leave it and it became waste material and deposited in the wetlands. This also reduced the extent and water holding capacity of wetlands (Fgure15).

Figure 15: Dumping and village expansion around wetlands

It was also observed that to get arable land the local community needs to diminish the wetland part of the area using different mechanisms such as dumping (through solid and liquid waste material in and around the wetland) and water diversion (Figure15). Due to, high rate of population pressure and introduction of new irrigation technology, farmland expands in and around the wetlands (Figure20 and 22). At every year considerable amount of new farmland for irrigation were generated (Figure16). Accordingly, the respondents witnessed that farmland expansion is the major factor of wetland change.

The expansion of irrigation increases at alarming rate since 2003 due to the introduction of water pumping technology and increasing of private agricultural investment in the area (figure16, figure20 and figure 22).In 2007 there was 5ha old and 105 newly developed irrigation farmlands. But within seven years the generation of new irrigation land increased to 2088.5ha and old irrigation increased in to 7664ha (Figure16).Figure16 depicts the irrigation trend of Dawa Chefa Woreda. Due to the introduction of new water pumping technology(Figure22) irrigation activity increases at alarming rate (Figure16).It increased by 250ha,571.8ha,956.3 and 2088.5ha in 2011,2012,2013 and 2014 respectively. This highly affects the water volume and land area extent of the wetland. The rate of increment of irrigation land was 582.4ha per year.

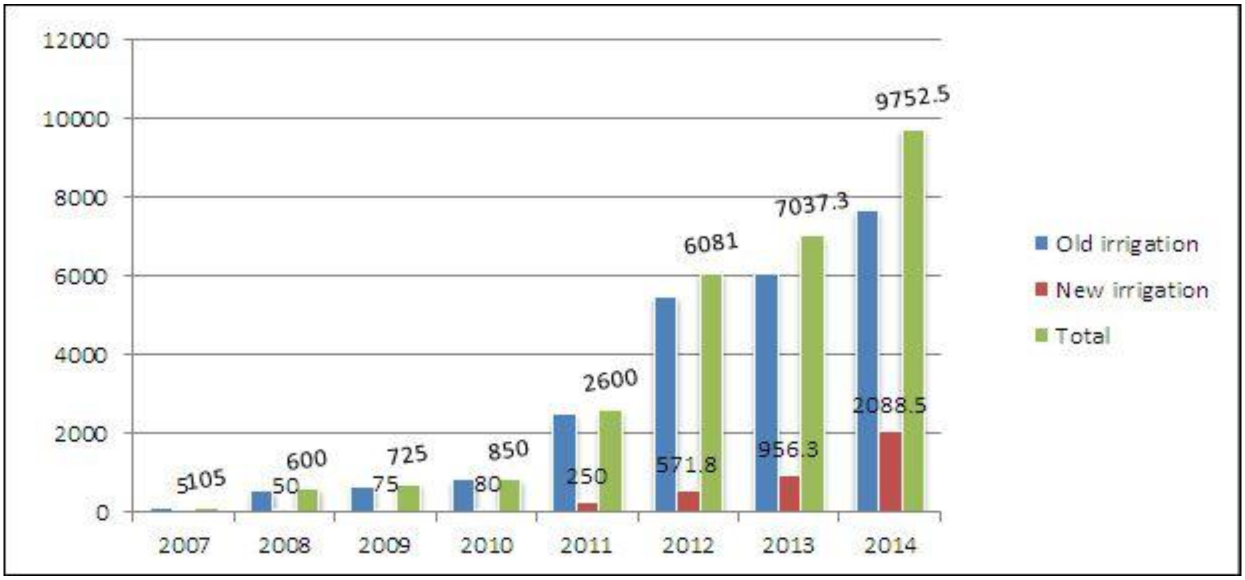

Figure 16.Trend of irrigation (Source: Irrigation office of Dawa Chefa Wereda)

Even if the wetlands are the main sources of food and water for cattle of nomads and farmers, over grazing causes loss of wetlands in Dawa Chefa area (Table18).More than 88% of respondents replied that over grazing highly affects wetlands ecosystem of Dawa Chefa area. Specially, nomads graze the wetlands day and night almost for over 8 months (till summer season comes) (Table18).

Figure 17. Partial view of herds of nomads around the wetlands

Figure 21.shows the inverse relationship of population growth and wetland extent. When population increased loss of wetlands also increased. Thus, population pressure becomes a major factor for wetland loss.

4.2.4 Socio-economic effect of wetland change

4.2.4.1. Characteristics of households

To assess the socio economic effect of the wetland 160 respondents were involved. Of these 73.8% was male and 26.3% were female respondents (Appendix 1). Regarding age3%, 6.3%, 59.4.8% and 31.3% of the respondents were aged 20-30, 31-40, 41-50 and above 50, respectively. With regard to occupation, 58.8% of the respondents were farmers, 12.5%, nomads, 5.6% retired, 3.5% house wives, 3.1% government employees and 1.3% NGO workers. For the rest of the information about house hold characteristics see appendix 2.

4.2.4.2 Social effect of wetland loss

Conflict is prevailed between the nomads and farmers of the local area due to both need land for different purpose (Table18). About, 87.5% of the respondents replied that the loss of wetland led to disagreement between nomads and farmers. The nomads depend on the wetland for about eight months to graze their herds each year. Hence, they need the land be out of any farming activity. Thus, the nomads resisted any activity which was run by the government in and around the wetland. They sometimes disagree with the strategies of the government about the wetland (Table18).

Table 18 Social effects of wetland change

Variables	Yes		No	
Social effects of wetland loss	Number of respondents	%	Number of respondents	%
Conflict	140	87.5	20	12.5
Between nomads and farmers	155	96.9	5	3.1
Between nomads and gov't	115	71.9	15	28.1
Between farmers and gov't	13	8.1	147	91.9
Religious conflict	0	0	149	93

4.2.4.3 Economic effect of wetland loss

The loss of wetland affects the economic aspect of Dawa Chefa area in to two contradictory ways. On one hand, when wetland loss increases swampy plants and animals also decreases and even disappear. As depicted in (Table 20) 98.8% respondents agreed that the reduction of filla was one of the main economic effects of wetland loss. Filla is one the most economically very important mangrove in the wetlands. People, especially nomads construct or made their house and house hold materials such as mattress and service flat from Filla (Figure18).

Figure 18: Houses made from Filla mangrove

On the other hand when wetland decreases agricultural land and grazing land increased. This increased agricultural production in Dawa Chefa area (Table 20). About 95% the respondents responded that agricultural land and production increases due to the fact that the wetland is very fertile and suitable for modern technology application (mechanized farming) (Figure20). Table19 reported that the irrigation land size of each crops increased from 2011 to 2013 except spices.

Farmers produce agricultural production three times per year from wetlands. Most of the productions are cash crops(Table19 andTable21).Sample respondents presented that these crops are produced not only for consumption purpose but also export to different part of Ethiopia(Table 21).Table21 presented that irrigation farm production (quintal) of cereal crops, vegetables and fruits increased from 1800,17556 and113,750 in 2012 to 171,212,130,527 and 342,425 in 2013 respectively. This showed that alarming rate increment of farm production at the expense of wetland loss in the study area.

Table 19. Land area share of crops in irrigation farm

Types of Crops		2011	2012	2013
1.Cereals		1321.75ha	1651.9ha	1580ha
	2.1 Vegetables	2481ha	3031ha	4666.2ha
2.Commercials	2.2 Spices	483.6ha	397ha	309ha
	2.3 Fruits	1545.5ha	1945ha	2873ha
	2.4 Others	249.15ha	12.4ha	325ha
Total		6081ha	7037.3ha	9753.2ha

(Source: Irrigation Development Office of Dawa Chefa)

The other economic importance of the loss of wetlands was increment of grazing land. About 94.4% of sample respondents replied that loss of wetlands increased the extent of grass land areas. The grass lands support a significant amount of herds of nomads and farmers. Nomads graze the wetland peripheral area for around eight months (from Hidar to Sene) without any additional food source for their animals (Figure17).

Table 20. Economic effect and factor of wetlands loss

Variable	Yes		No	
Economic Effect of wetland loss	Number of respondents	%	Number of respondents	%
Decrease grazing land	6	3.75	151	94.4
Increase grazing land	151	94.4	0	0
Loss of Filla	158	98.8	0	0
Reduction of ground water	135	84.4	5	3.13%
Increase farmland	155	96.9	2	1.3%
Decrease farm production	4	2.5	0	0
Increase farm production	152	95	0	0
Factors of wetland loss				
Population growth	145	91.3	14	8.8
Farmland expansion	150	93.8	10	6.3
Sedimentation	140	87.5	20	12.5
Over grazing	142	88.8	18	11.25
Lack of annual rain fall	10	6.3	150	93.8
Dumping	153	95.6	7	4.4
Eucalyptus tree farming	74	46.2	86	53.8
Urbanization	140	87.5	10	6.3

4.2. Discussion

The LULC of the study area have undergone significant modifications and conversions over the last 30 study years (Table16).On the constant area of land different LULCC dynamics have been observed. The highest magnitude and rate of wetland change had been observed between 2000 and 2013 of the study years (Figure19 and Appendix4). The extent (magnitude) of wetlands lost were 25551.32ha between1984 and 1993,

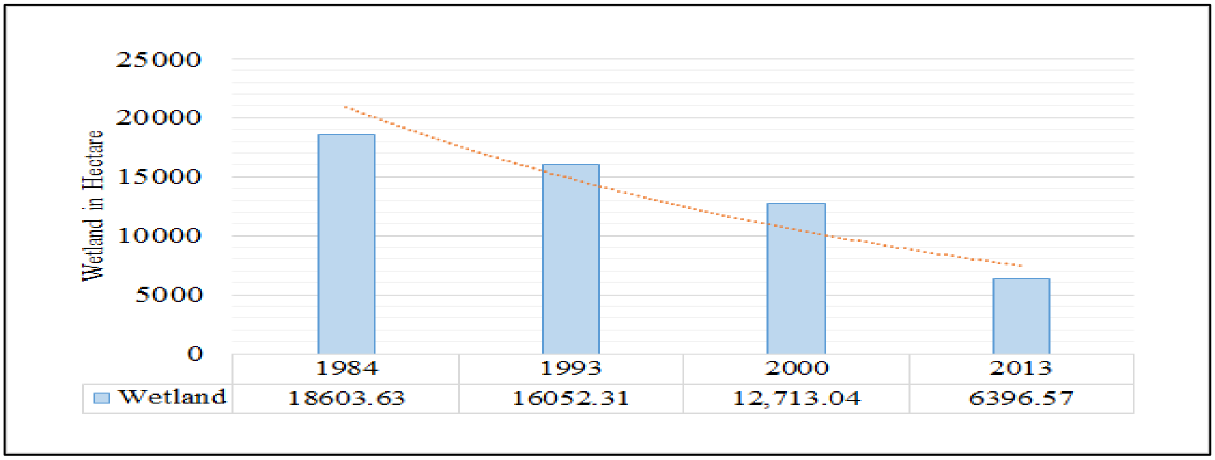

Figure 19.Total wetland change over time (in hectare)

This shows that the study area were under a serious LULCC dynamics. In general, in the last 30 years wetlands, bush and forest were decreased.

Results showed that increment of farm, urban and grass at the expense of other LULC classes resulted from population pressure and related activities. A research which was studied in 2010 by Abiy in the Northern Central highlands of Ethiopia in the case of Anstokia stated that LULC dynamics of the country highly affected by agricultural expansion at the expense of other LULC classes. Because the wetlands in the low and mid-highland areas has been converted in to other land cover classes particularly to farmland and grazing land.

Northern highlands due to high population growth coupled with serious marginal lands such as water logged plateau, swampy, pond, marshy areas, and basins were brought under cultivation; and vast areas of forest and woodland were cleared (Markos Ezra, 1997 and Kebrom et al, 2000). Moreover, Solomon (1994) showed that land-use and land-cover changes and socioeconomic dynamics have a strong relationship; as population increases the demand for cultivated land, grazing land, fuel wood; settlement areas also increase to meet the growing demand for food and energy, and livestock population. Generaly, farmland and urban area increased while wetland and forest decreased from 1993 to 2000. Therefore, agricultural expansion at the expense of other LULC classes stills a serious problem in the northern highlands in general the study area in particular (Figure20).

Figure 20Agricultural activities surrounding the wetlands

The population growth and wetland loss of the study area have direct relationship (Figure21). When population growth increased, wetland loss also increased. In this regard, Girmay (2003) stated that the Ethiopian highlands have experienced a serious LULC dynamics for the last hundred years due to continuously growing population. This study also approved that population pressure adversely degrade natural resources and it is the means for other related factors.

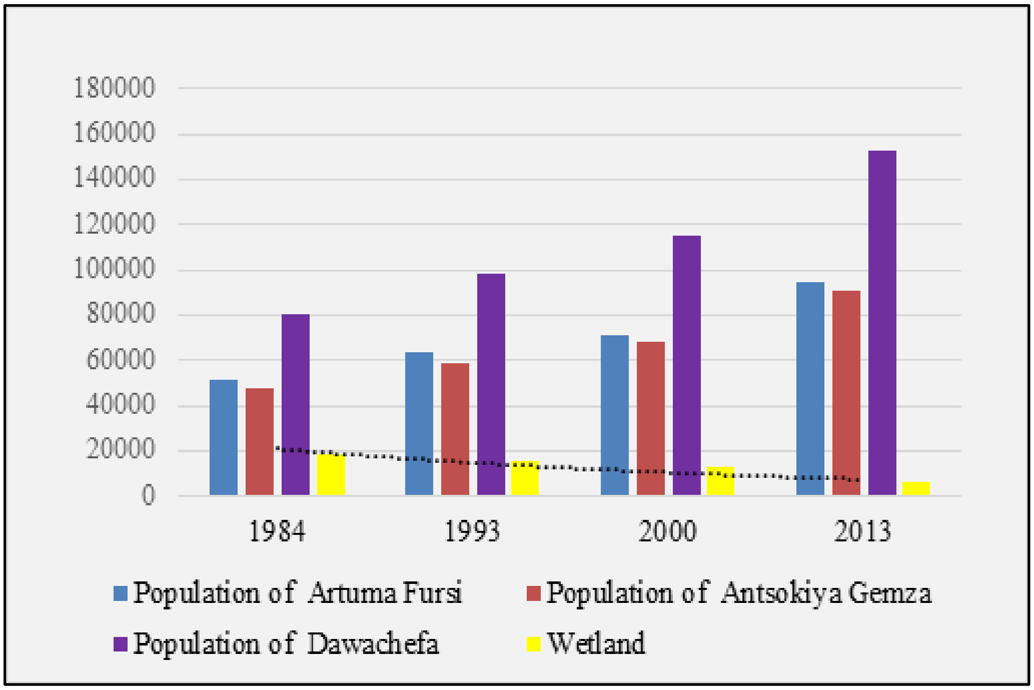

Figure 21Wetlands reduction and population growth (1984-2013)

Human born factors are not the only one on LULC change of the landscape natural factors are also play a significant role in modification and conversion of the landscape LULC mosaic (Gimay, 2003). Besides, natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics may also initiate modifications upon land cover. However, recently human activities and social factors were recognized to have a paramount importance for understanding of land-use and land-cover change.

Land clearing for agriculture that has been the most significant process by far and is a process that continues today. Human factors are resulted in fast often and proximate (direct) causes of LULC change on the environment (Blair and Dockray, 2004). These are immediate actions of local people in order to fulfill their needs from the use of the land (Geist and Lambin, 2002). In agreement with Turner and Meyer (1994), agricultural expansion, wood extraction, infrastructure expansion and others that change the physical state of land cover through time and space. The study on landscape pattern change of wetland showed that wetland ecosystems are the front line for human intervention since they are relatively resource full areas (Shou, 2008).

Wetland of Dawa Chefa area was highly exposed to human intervention, especially to agricultural and related activities due to the topographical and climate condition of the area.

Farmers produced cash crops three times per year as the wetlands are very accessible to roads. Particularly, mechanized farms like Elfora around and in the wetland that highly utilized considerable amount of water from the wetlands and applied modern farming technologies (Figure22).Similarly,USEPA(1994) reported that agricultural land expansion and other agricultural activities such as harvesting forest products; minor drainage; maintenance of drainage ditches; construction and maintenance of irrigation ditches; construction and maintenance of farm or forest roads; maintenance of dams, dikes, and levees; direct and aerial application of damaging pesticides (herbicides, fungicides, insecticides, fumigants); and ground water withdrawals performed in wetlands can degrade and alter a wetland's hydrology, water quality, and species composition.

Although grazing animals on wetlands have economic advantage, it is one of the prominent factors for the reduction of wetland in the study area. Cognizant to this finding, A technical report by Ontario Ministry of Natural Resources(1993) presented that excessive amounts of animal waste reaching wetlands in runoff from agricultural operations, including confined animal facilities, can cause eutrophication. Moreover, Ndzeidze (2008) revealed that cattle traffic may cause dens and tunnels to collapse the wetlands. As vegetation is reduced, stream banks can be destroyed by sloughing and erosion.

Stream bank destabilization and erosion then cause downstream sedimentation preventing runoff filtration, increasing stream temperatures, and eliminating food and cover for fish and wildlife (USEPA et al., 1994). However, EPA (2004) argued that if stocking of livestock is well managed, grazing can coexist with wetlands, benefiting farmers and increasing habitat diversity.

There are three ways of water pumping systems in the wetland area pedal pump, motor pump and traditional pumping systems (Figure 22).The introduction of new water pumping technology facilitates agricultural expansion and investment in the surrounding of the wetland. This caused the loss of high extent of area of wetlands with in short period of time (Figure22). This indicates that wetlands in Dawa Chafe have been dwindling.

Figure 22. Partial view of irrigation activity in and around the wetlands

The wetlands of Dawa Chefa area surrounded by towns. As a result waste dumping was appeared as serious factor of wetland loss through throwing waste materials into the wetland. Particularly, Kemissie town used the peripheral part of the wetlands as dumping site. Deposition of waste material in and around the wetland affects the water holding capacity of the wetlands. Other factors of wetlands loss are sedimentation, eucalyptus tree farming. Eucalyptus great impact for loss of wetland.

Sedimentation was found to be one of the main factors for wetland losses next to agriculture and population pressure. This is because of land degradation in and around the wetland catchment. Moreover, Abiy (2010) stated that serious land degradation and erosion in the upper catchments adversely affect the low laying areas. Huge flooding and runoff erosion transport sands, gravels and boulders to the low laying areas and fill them with these materials. Most part of Dawa chefa area is low laying are surrounded by mountains and hills from which rivers flow in to the wetlands.

The wetland loss showed two contradictory socio economic effects. On one hand the loss highly affected wetland ecosystem and biodiversity. Filla and other mangroves which are economically important were decreased. Research conducted in Hoor Al Azim in Iran showed that loss of wetland results in the loss of surface water quality, destruction of wild life habitat, loss of biodiversity, flooding, erosion and environmental degradation (2012). Moreover, by Gete Zeleke(2000) shows that land degradation is a long-term process which the effect and steady expansion is hardly noticed until it manifests itself with disastrous drought and famine.).

On the other hand, wetlands loss increased the agricultural productivity of the area by increasing the land hold chance of households (Table21). This also a contradicting finding with reduction of ground water. For agricultural productivity ground water accessibility is very important as it supports the surface water accessibility. But, for the time being agricultural productivity increased with the loss of wetlands. This may not be happened for a long sustainably. Study about Landscape Dynamics and Soil Erosion Process Modeling in the Northwestern Ethiopian Highlands by Gete Zeleke(2000) presented that land degradation is a long-term process in which the effect and steady expansion is hardly noticed until it manifests itself with disastrous drought and famine.

Table 21.Amount of irrigation farm crop production in quintal per year

Types of crops	Amount of production in quintal	
	Year	
	2012	2013
Cereals	1,800	171,212.6
Vegetable	17,556	130,527
Spices	0	156
Fruits	113,750	342,425.2
Others	0	450
Total	133,106	644770.8

(Source: Dawa Chefa Irrigation Development Office, 2012 and 2013)

Chapter 5: Conclusion and Recommendation

5.1 Conclusion

Wetlands have been decreased due to anthropogenic and natural factors. Consequently, the ecological and socio-economic service of the wetlands has been diminished at an alarming rate. The study was carried out to assess the spatio-temporal change of wetlands of Dawa Chafa area. RS and GIS techniques were applied to analyze and detect changes of wetlands based on multi-temporal satellite data. Land sat imageries during 1984, 1993, 2000 and 2013 were utilized to extract wetlands change in the study area via analysis of LULC changes during these years. The change detection analysis was carried out using post classification comparative analysis of independently produced classifications from different dates (map-to-map comparison) and image-to -image comparison. In the case of the post-classification method, imageries from different archives in different year interval are classified and labeled individually.

The study showed that the wetland has changed into different LULC types. Even though many changes have observed between 1984 and 2013, the highest negative rates of changes were seen in wetlands and forest which was averagely decreased every year by 37.4% and 37.95% respectively. Whereas the highest positive rate of changes were seen in built up and farmland areas which were averagely increased by 95.1% and 49.1% per annum respectively. Moreover, the LULCC matrix showed that the rate of change of wetland loss of Dawa Chefa area increased alarmingly in space and time.

The LULC class to which highest magnitude of wetland was changed in to was taken as major factor of wetland reduction. The increase of urban/built up and agricultural land use are mainly at the expense of other land uses attributed to population growth in the last 30 years. Thus, farmland and urban expansion found to be the major factors of wetland loss. Because both took the highest share of land area from wetland through the course of the study years. Besides farmland and urban expansion, sedimentation, dumping, overgrazing and eucalyptus tree farming were found to be the factors of wetland change.

The decrement of the wetlands affected the socio economic aspect of the study area in to two contradictory ways. On one hand, agricultural land and production increased at the expense of wetlands loss. On the other hand, following the loss of the wetland mangroves which are important for the construction of house and household material has decreased. The depletion of resources of wetlands led to conflict among the nomads and farmers.

Generally, GIS and RS and other qualitative based study confirm that there is massive wetlands loss caused dominantly by anthropogenic factors. Consequently, wetland resources have been declining and thereby increase environmental, economic and social costs. This threatens the sustainability of the wetland resources for the future in Dawa Chefa, in the north central highlands.

5.2 Recommendations

- Wetlands and forest decreased while agricultural land and urban area increased from time to time due to, dominantly, population pressure which affects the wetland in multidimensional way. This causes urban expansion, farmland expansion, overgrazing and eucalyptus tree farming. Therefore to safeguard the wetland in the area there should be enforceable land use polices and alternative income sources for the surrounding people that depend on the wetland as source of income. Moreover, there should be proper land use plan and management. The government should adopt policies and frameworks that are used as a guide tool for the conservation and wise use of wetlands and their resources in the area. These policies have to include the forestation and reforestation of the upper catchment to reduce the direct impact on wetland loss.

- In the study area farmers tend to expand their farm to the wetland as well as they plant eucalyptus trees, which have the potential of drying ground water, in and around the wetland. This unmanaged agricultural land expansion has increased the shrinking of wetland area extent and water volume of the study area. Hence, promoting awareness on farmers requires policy makers better understand how local think about the role of unmanaged agricultural expansion and related activities at the expense of wetlands in their future lives. Policy makers should adopt agricultural land policies that are compatible with protection and conservation of wetlands. They should also Provide and introduce agricultural activities that can coexist with the wetland development and management.

- Nomads of the area lack motivation and awareness regarding wetland protection. Nomads have also over grazed in and around the wetland day and night. They made temporary and disorganized houses close to the wetland. The accumulation of waste material from herds and materials that was used to make temporary houses reduced the water holding capability of the soil of the wetland. Therefore, the government and concerned body should create awareness for the nomad about wetland protection. The government has to provide alternative economic activity (income source) for the nomads to stop over rearing of cattle which are above the carrying capacity of the wetland and the surrounding. In addition to this, the government should adopt settlement program to settle down the nomads in an organized and compatible manner with wetland development. There should be strong policy and strategy that govern the expansion of urban and investments area to the wetland.

- Waste dumping in to rivers that cross towns of Kombolcha, Antsokia and kemissie and directly in to the wetland highly affect the wetland ecosystem and facilitate wetland loss. Hence, the municipalities of Kombolcha, Kemissie and Atsokia towns should create awareness for the urban people about the solid and liquid waste that are thrown in to the rivers and wetlands will affect the wetland. It should adopt policies and strategies that protect the wetland from being dumping site.
- The reduction of the wetland has shown two contradictory impacts on the socio economic aspect of the area. On one hand, when wetland decreased the economically beneficial mangroves decreased. On the other hand, when wetland decreased agricultural land accessibility and production increased, especially for the newly emerged farmlands. If policies and strategies were not adopted to conserve wetlands, agricultural production would diminish. This is because of that the soil of the farm land will exhaust. Thus, in order to safeguard the biodiversity of the wetlands ecosystem and make the agricultural production sustainable awareness should be created on the surrounding people how to use the wetland properly and wisely. Moreover, Science-based policies and strategies should be adopted to practice farming and related activities which are friendly with the wetlands development in particular and the environment in general. Different governmental and non-government agencies should involve in conservation and inventory of the wetland. Develop a policy for wetland conservation, restoration and monitoring in Dawa Chefa and surrounding area. On

top of this, reserves and management zones should be established adjacent to wetlands. To sum up, institutional collaboration among those various ministerial offices at different administrative hierarchies is required for sustainable wetlands development and conservation.

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Appendices

Appendix: 1 Agro-ecology of the study area

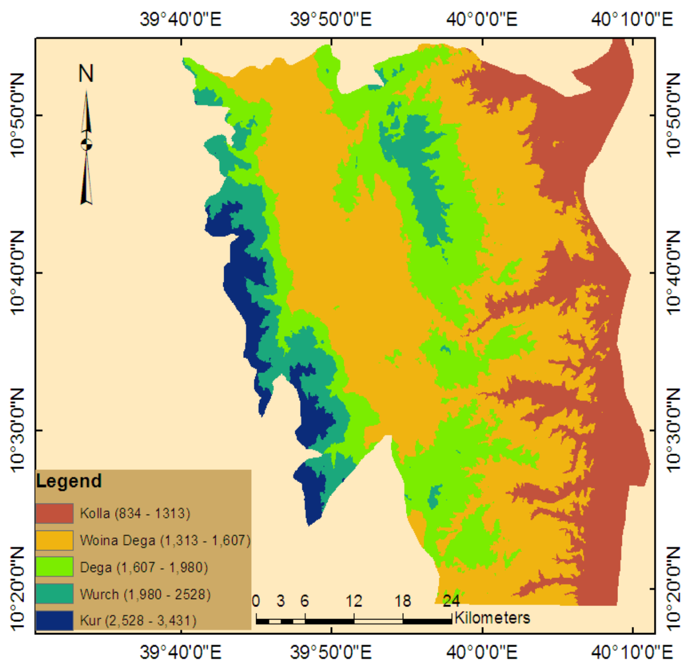


Figure Agro-Climatic condition of the study area.

Appendix:2 Characteristics of Sample house holds

variables	Respondents	
	Total(n)=160	
Sex	n	%
Male	118	73.8
Female	42	26.3
Age		
20-30	5	3
31-40	10	6.3
41-50	95	59.4
Above 50	50	31.3
Family size		
1-4	125	78
5-8	35	21.9
≥9	0	0
mean		
Educational status		
illiterates	25	15.6
Primaryedu*****- (1-8)	49	30.6
Secondary edu-(9-12)	78	48.8
College diploma	7	4.4
College degree	3	1.9
Marital status		
single	10	6.3
married	142	88.7
divorced	5	3.1
widowed	3	1.9
Major occupations of hh heads		
Government employees	5	3.1
NGOs employees	2	1.3
student	6	3.8
Farmers	94	58.8
Nomadis	20	12.5
House wife	4	3.5
Business person	20	12.5
Retired	9	5.6
Religion		
Christians	31	19.4
Muslim	129	80.6
Average Income of the hhs.		
950 Birr per month		

Appendix 3: Economic effects and factors of wetland loss

Variables	Yes		No	
Economic Effect of wetland loss	Number of respondents	%	Number of respondent s	%
Loss of Filla	158	98.8	0	0
Reduction of ground water	135	84.4	5	3.13%
Increase farmland	155	96.9	2	1.3%
Decrease farm production	4	2.5	0	0
Increase farm production	152	95	0	0
Factors of wetland loss				
Population growth	145	91.3	14	8.8
Farmland expansion	150	93.8	10	6.3
Sedimentation	140	87.5	20	12.5
Over grazing	142	88.8	18	11.25
Lack of annual rain fall	10	6.3	150	93.8
Dumping	153	95.6	7	4.4
Eucalyptus tree farming	74	46.2	86	53.8
	140	87.5	10	6.3

Appendix 4: Rate of change of wetlands

Rate of change of wetlands in hectare per year								
1984 to 1993	numbers of years	1993 to 2000	numbers of years	2000 to 2013	numbers of years	1984 to 2013	numbers of years	ye ars
-283.48	9	-477.8	7	-485.9	13	-406.9	30	

Appendix: 5

Questionnaire to be filled by House Holds

MEKELLE UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND LANGUAGES

SCHOOL OF GRADUATE STUDIES

DEPARTEMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

Questionnaire

Introduction

This questionnaire deals withSocio economic effects and factors of wetland loss. The purpose of this research is purely academic and you have been randomly selected for the purpose of this research to represent other households in this Kebele. Thus, the fact that you have been selected is quite coincidental and your participation in this questionnaire is voluntary. The information you provide will be treated as confidential. It will be processed in computer in such a way that no personal identification will be possible. To obtain reliable and scientific information it is necessary that you answer the questions as honestly as you can.

I greatly appreciate your cooperation in advance!

- **General Instruction**
- Circle the right answer for each question from the given alternatives

➢ **Basic characteristics of informants**

- Address:
- Sub-city:________________
- Sex of respondent's : a. Male b. Female
- Positions in the house hold: a. Head b. Member
- Age of respondent: a. 20-30 b.31-40 c.41-50 d. above51

➢ **Family size**

S.N.	Age	Number of families	Sex		Total
			Male	Female	
a	Children (<15)				
b	Adults (15-64)				
c	Old (>64)				
Total					

- **Educational status:**

    a. Illiterate b. Primary education (1-8) c. Secondary education (9-12)

    d. college diploma e. college degree f. other specify

- **Religion**: a. Christian b. Islam c. Other
- **Marital- status:** a. Single b. Married c. Divorced d .Widowed
- **Occupation:** a. Government employee b. NGOs employee

    c. Student d. Dairy farmer e. Daily laborer

    f. House wife g. Businessperson h. Retired i. Other

Part I

1. Social effect of wetland loss

1.1 Is there any Disagreements following the reduction of the wetlands ?

A. Yes B.No

1.2 If your answer is yes, is it among farm house holds?

A.yes B.No

1.3Is the conflict among nomads? A.Yes B.No

1.4Is it between nomads and farmers? A.Yes B.No

Does the wetland loss have any religious conflict? A.Yes B.No

1.5Is there any disagreement between nomads and people around? A.Yes B.No

Part II

2Economic effects of wetland loss

2.1Does the decreasing condition of wetland reduced grazing land? A.Yes B.No

2.2Does the loss increase grazing land? A.Yes B.No

2.3Does the wetlands loss affect wetlands ecosystem? A.Yes B.No

2.4does the wetland reduction decrease agricultural land? A.Yes B.No

2.5 Does it increase agricultural land? A.Yes B.No

2.6Does wetland reduction increase farm production? A.Yes B.No

PartIII

3.Factors of wetlands reduction

3.1 Do you think that population growth s the cause for wetland loss? A.Yes B.No

3.2 Do youthinkthat farmland expansion affect the wetlands? A.Yes B.No

3.3 Do you think that sedimentation decrease the extent of wetlands? A.Yes B.No

3.4 Do you think that over grazing affects wetlands? A.Yes B.No

3.5 Do you observed that lack of rainfall affect wetlands? A.Yes B.No

3,6 Do you think that eucalyptus tree farming affect wetland ecosystem? A.Yes B. No

3.7 Did you see people waste material in the wetland and arruond?A.Yes B.No

Thank you!!!

Appendix:6 Rainfall Data of the study area

Kemisse monthly total rainfall												
Year	**jan**	**feb**	**mar**	**apr**	**may**	**jun**	**jul**	**aug**	**sep**	**oct**	**nov**	**dec**
1963	8.2	115.3	166.0	274.0	150.0	25.8	209.8	330.3	175.0	66.2	58.2	63.7
1964	24.6	16.2	16.5	88.1	53.0	25.3	431.8	387.5	165.7	29.0	1.0	61.1
1965	11.5	0.0	34.7	32.0	1.0	0.0	140.1	214.1	46.4	27.0	75.0	0.0
1966	13.0	95.3	21.2	123.7	11.5	33.5	120.6	228.7	116.0	58.3	0.0	0.0
1967	0.0	2.0	100.2	72.0	103.4	44.0	271.9	190.6	85.6	0.0	0.0	0.0
1968	2.0	104.7	35.8	98.1	22.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1969	128.8	92.0	73.7	141.3	43.5	11.0	308.2	217.9	42.7	54.0	0.0	0.0
1970	92.0	84.6	115.0	16.8	15.6	0.0	289.9	373.6	87.0	12.8	0.0	16.0
1971	14.4	0.0	29.6	18.5	101.1	0.0	167.5	220.4	96.9	3.0	56.0	55.9
1972	4.6	76.6	50.3	173.1	36.8	84.8	207.7	105.8	70.8	29.6	0.0	0.0
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1974	0.0	15.2	122.6	15.2	86.1	103.4	259.0	353.7	186.0	21.0	0.0	0.0
1975	39.8	54.2	27.2	47.8	24.0	67.5	221.3	370.1	114.2	10.5	0.0	1.0
1976	0.0	9.0	47.0	126.6	87.0	40.0	245.7	263.0	73.0	12.6	56.9	16.0
1977	41.8	8.5	40.6	101.8	123.1	0.0	355.3	269.0	65.8	106.3	7.0	0.0
1978	0.0	117.1	14.5	8.6	33.8	22.1	268.1	261.3	118.3	0.0	0.0	0.0
1979	97.9	15.2	64.5	20.0	186.3	34.6	210.5	219.0	183.2	75.8	0.0	0.0
1980	0.0	15.3	35.7	63.0	17.2	3.3	257.5	320.0	105.3	94.0	0.0	0.0
1981	0.0	10.0	217.5	121.9	24.4	0.0	319.6	447.9	74.6	69.6	0.0	22.6
1982	153.5	8.3	39.5	56.1	60.5	0.0	86.3	227.3	196.5	112.7	160.7	32.3
1983	11.0	9.4	183.5	43.6	0.0	0.0	0.0	233.2	77.7	45.7	0.0	0.0

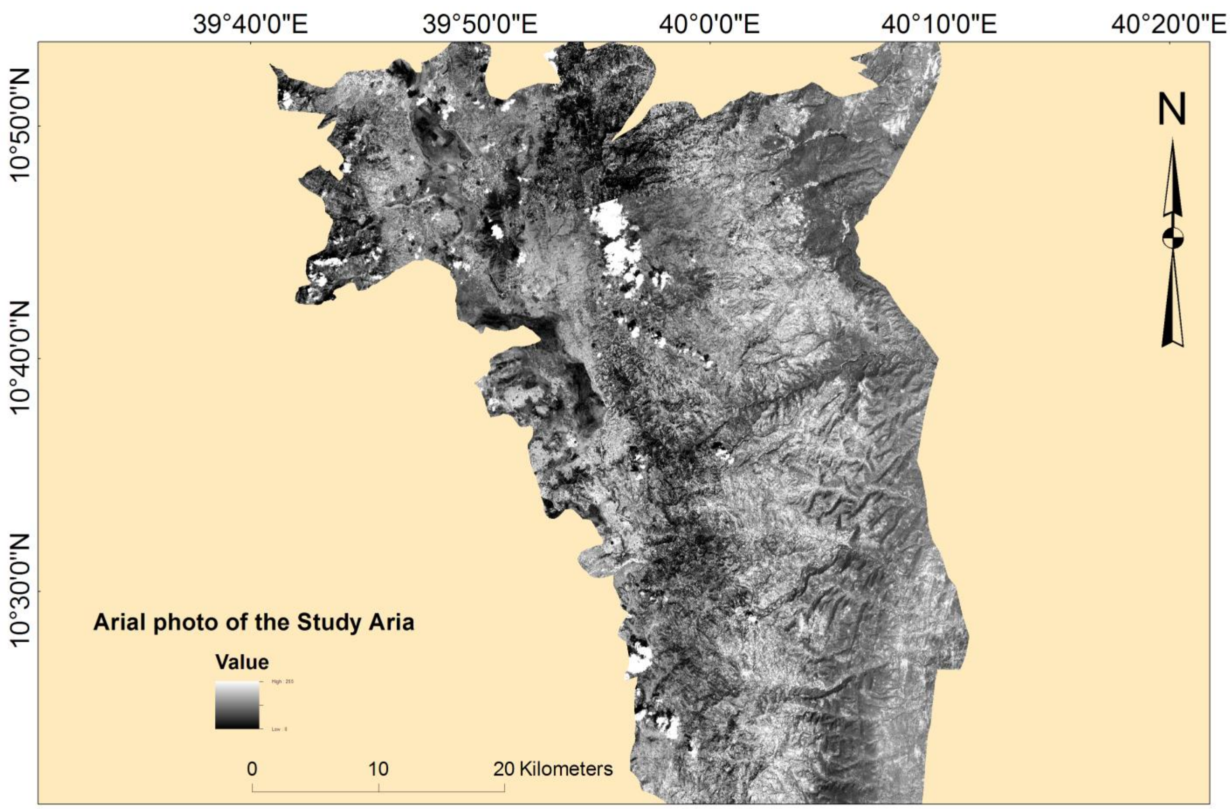
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	69.2	216.5	64.6	0.0	227.9	312.9	151.1	22.3	0.0	0.0
1986	0.0	38.5	39.9	158.0	41.3	132.5	192.8	311.1	226.9	3.1	0.0	0.0
1987	0.0	45.4	90.9	87.1	137.6	2.2	16.1	257.8	90.3	16.4	0.0	36.4
1988	0.1	133.7	0.4	154.0	0.0	17.0	305.8	422.5	229.9	25.4	0.0	0.0
1989	32.8	27.6	187.4	0.0	11.1	11.2	154.6	192.5	31.7	63.5	0.0	0.0
1990	22.0	110.0	54.0	0.0	25.0	0.0	199.0	108.5	153.1	0.0	0.0	0.0
1991	0.0	0.0	53.4	17.9	66.8	8.5	0.0	0.0	125.7	0.0	0.0	0.0
1992	112.2	0.0	12.4	42.5	12.5	0.0	166.0	200.0	36.3	9.9	12.4	12.1
1993	0.0	25.6	5.0	285.6	202.4	3.4	194.8	212.6	100.7	98.0	0.0	0.0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	0.0	71.4	118.9	193.8	46.2	57.9	377.4	336.7	125.8	0.0	0.0	85.9
1996	60.2	0.0	161.8	53.0	201.7	42.4	248.2	490.9	110.4	0.0	84.6	0.0
1997	50.9	0.0	61.0	81.9	5.3	87.4	364.1	184.5	33.3	151.5	160.7	0.0
1998	30.5	22.6	44.5	62.5	56.9	2.2	480.3	249.6	95.2	92.1	0.0	0.0
1999	51.8	0.0	21.9	0.0	20.5	10.6	451.0	313.5	78.0	207.1	18.6	2.6
2000	0.0	0.0	0.0	82.4	95.5	8.6	303.3	468.3	181.8	51.6	30.5	27.6
2001	1.7	0.0	110.7	10.7	102.6	7.8	401.2	295.2	68.8	8.9	0.0	1.4
2002	0.0	0.0	73.2	72.8	53.4	2.4	281.9	255.0	79.2	0.0	0.0	243.7
2003	11.0	48.4	121.7	185.3	0.0	25.2	239.9	408.3	257.3	0.0	19.2	55.6
2004	53.9	23.1	51.1	156.1	10.4	47.4	223.1	322.9	88.0	64.2	59.5	6.0
2005	13.3	5.0	24.2	63.2	127.0	27.0	241.0	221.5	88.3	20.3	19.0	0.0
2006	44.8	0.0	57.6	87.3	18.1	10.3	0.0	0.0	0.0	0.0	0.0	0.0
2007	12.2	7.8	27.9	150.7	31.4	43.1	308.2	289.4	110.0	37.8	2.0	0.0

2008	30.9	0.0	0.0	18.8	38.2	36.5	265.0	211.9	117.0	17.5	49.2	0.0
2009	23.1	15.6	8.5	18.9	31.0	35.0	204.0	310.3	28.0	60.8	22.0	57.9
2010	0.0	61.1	86.9	83.2	39.3	5.3	346.0	653.9	719.5	2.1	0.0	0.0
2011	0.0	0.0	91.3	44.5	96.8	98.8	184.4	265.6	351.0	0.1	49.6	0.0
2012	0.0	0.0	26.5	59.4	102	37.5	238	254.8	300	0.0	xx	xx
2013	4.2	0.0	109.8	20.3	33.1	0.0	337.1	447.0	61.1	91.6	6.8	0.0

Appendix: 7 Temperature Data of the study area

Kemmise avg max temp												
Year	**jan**	**feb**	**mar**	**apr**	**may**	**jun**	**jul**	**aug**	**sep**	**oct**	**nov**	**dec**
2004	xx	xx	xx	xx	xx	34	32	31.5	30	28.4	28.6	27
2005	27.6	31.9	32.1	31.2	31.7	34.7	31.4	31.5	31.3	30.9	30.2	29.1
2006	29.6	30.7	30.7	30.4	33.1	34.7	31.1	29.9	30.5	30.9	30.6	29.0
2007	27.3	29.9	32.0	31.1	33.5	33.6	29.9	29.8	30.4	29.9	28.9	28.5
2008	29.1	29.0	32.4	32.1	33.5	34.4	32.1	30.2	29.8	29.6	27.7	28.3
2009	28.1	29.7	31.6	32.2	34.1	35.7	30.9	30.7	31.3	29.6	29.9	28.0
2010	28.6	28.9	29.3	32.0	33.3	35.7	31.6	29.2	30.3	30.4	29.0	27.6
2011	27.8	30.4	29.6	32.5	31.8	34.5	32.7	29.9	31.1	30.8	28.4	29.0
2012	30.4	31.2	32.5	31.8	34.0	36.4	xx	30.8	31.6	31.6	xx	xx
2013	31.3	32.5	33.6	34.1	35.2	36.7	31.6	30.3	31.9	30.2	30.2	29.6
Kemmise avg min. temp.												
Year	**jan**	**feb**	**mar**	**apr**	**may**	**jun**	**jul**	**aug**	**sep**	**oct**	**nov**	**dec**
2004	xx	xx	xx	xx	xx	15	15	16.1	14	11.1	8.5	11
2005	12	10.4	14	15	15	15	15	15.7	14	9.5	7.9	6.4
2006	11	12.9	15	15.4	15	17	17	16.6	15	12.6	11.1	13
2007	13	14.4	14	16.1	15	18	17	16.7	15	10.5	9.2	7.4
2008	11	10.4	9.6	14.8	17	17	18	16.6	15	12.1	10.8	12
2009	11.0	12.3	13.6	15.3	14.6	17.3	17.3	16.9	14.6	12.6	9.5	14.0
2010	11.3	14.9	14.7	16.8	17.2	17.5	16.4	16.8	15.4	12.0	10.1	10.3
2011	12.3	11.8	13.3	15.2	16.5	16.5	17.5	17.0	15.9	11.1	13.1	9.2
2012	11	9.5	13	16.4	16	17	17	16.9	14.7	10.3	xx	xx
2012	10.7	10.6	16.1	17.4	16.6	17.3	16.8	16.6	18.3	9.0	11.9	8.5

Appendix 8 Arial photo of the study area



Appendix 9 Partial view of wetlands